Fishery Data Series No. 91-15

Stock Assessment of Arctic Grayling in the Salcha, Chatanika, and Goodpaster Rivers

by

Robert A. Clark,
Douglas M. Fleming,
and
William P. Ridder

June 1991

Alaska Department of Fish and Game

Division of Sport Fish

FISHERY DATA SERIES NO. 91-15

STOCK ASSESSMENT OF ARCTIC GRAYLING IN THE SALCHA, CHATANIKA, AND GOODPASTER RIVERS[1]

By

Robert A. Clark,
Douglas M. Fleming,
and
William P. Ridder

Alaska Department of Fish and Game
Division of Sport Fish
Anchorage, Alaska

June 1991

[1] This investigation was partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-6, Job No. R-3-2(a).

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF APPENDICES (Continued)

LIST OF APPENDICES (Continued)

ABSTRACT

Arctic grayling *Thymallus arcticus* were captured by pulsed direct current electrofishing in the Salcha, Chatanika, and Goodpaster rivers in 1990. Stock assessment was accomplished through estimation of population abundance, age composition, and size composition. Population abundance in a 36.8 kilometer section of the Salcha River was 5,792 (standard error = 659) Arctic grayling greater than 149 millimeter fork length. Population abundance in a 28.8 kilometer section of the Chatanika River was 19,306 (standard error = 3,197) Arctic grayling greater than 149 millimeter fork length. Population abundance in the lower 50.0 kilometers of the Goodpaster River was 7,113 (standard error = 489) Arctic grayling greater than 149 millimeter fork length. Age 3 Arctic grayling were most abundant in the sections sampled in all three rivers. Similarly, "stock" size Arctic grayling were most abundant in all three rivers. All historical data on age, size, and sex compositions, harvest and effort, and population abundance from 1952 to 1990 are presented.

KEY WORDS: Arctic grayling, *Thymallus arcticus*, population size, harvest, fishing effort, age composition, size composition, sex composition, relative stock density, electrofishing, movements, Salcha River, Chatanika River, Goodpaster River, Tanana River drainage.

INTRODUCTION

The Salcha and Chatanika rivers presently support two of the largest Arctic grayling *Thymallus arcticus* fisheries in the Tanana drainage of interior Alaska. Although these fisheries are large, very little is known about the population dynamics of Arctic grayling in these streams. In contrast, the Goodpaster River is a relatively small Arctic grayling fishery. However, Arctic grayling from the Goodpaster River stock are harvested in the Delta and Richardson Clearwater rivers (Ridder 1983). This is a major concern since the Delta Clearwater River supports the fifth largest Arctic grayling fishery in interior Alaska (Mills 1989).

Precise knowledge of fishery characteristics and the dynamics of Arctic grayling populations in these streams is of growing importance to fishery managers. Thus, a multiyear study of Arctic grayling populations in the Salcha, Chatanika, and Goodpaster rivers was initiated in 1989. This report is the second in a series designed to provide this information.

In conjunction with the present study, this report summarizes stock assessment work performed on the Salcha, Chatanika, and Goodpaster rivers from 1952 to 1989. By presenting all data pertinent to these fisheries, decisions regarding future research goals can be made. Summarized data will allow managers to assess the status of Arctic grayling stocks in the Salcha, Chatanika, and Goodpaster rivers.

The research objectives for 1990 were to estimate:

1) the abundance of Arctic grayling greater than 149 mm fork length in a 36.8 km section of the Salcha River;

2) the abundance of Arctic grayling greater than 149 mm fork length in a 28.8 km section of the Chatanika River;

3) the abundance of Arctic grayling greater than 149 mm fork length in the lower 50.0 km of the Goodpaster River;

4) the age composition of Arctic grayling in the Salcha, Chatanika, and Goodpaster rivers; and,

5) the Relative Stock Density (RSD) of Arctic grayling in the Salcha, Chatanika, and Goodpaster rivers.

Fishery Descriptions and Study Areas

The Salcha, Chatanika, and Goodpaster Arctic grayling fisheries have some distinct differences that affect the progress of stock assessment work. Each fishery is described by hydrologic characteristics, methods of access, and past performance of the recreational fishery. Historic population data are presented as a series of tables in Appendices A and B.

Salcha River:

As with other runoff streams of the Tanana drainage, the Salcha River flows south out of the Tanana hills into the Tanana River (Figure 1). The river is characterized by high gradient, with long shallow runs and exposed gravel bars. Holmes (1984) described four separate areas encompassing the lower 192 km of the Salcha River. The upstream section is characterized by a narrow (~18 m wide), shallow (~0.5 m deep) channel with numerous protruding boulders. Average water velocity in late June was 1 m/sec, with a gradient of 4.2 m/km. The upper midstream section is characterized by a wider (~33 m), deeper (~1.2 m) channel with no protruding boulders. Water velocity and gradient are similar to the upstream section. The lower midstream section is characterized by a 68 m wide and 2.1 m deep channel. Average velocity in this section was 0.8 m/sec, while average gradient was 1.8 m/km. The downstream section is characterized by a single, wide channel with a water velocity of 0.8 m/sec and a gradient of 1.1 m/km. Average stream flow in the downstream section during summer (May-July) has ranged from a low of 50.95 m^3/sec in 1980 to a high of 123.86 m^3/sec in 1984 (USGS 1976-1989). The majority of recreational fishing occurs in the downstream section (river kilometer 0 to river kilometer 80).

Recreational fishing targets Arctic grayling, chinook salmon *Oncorhynchus tshawytscha*, summer chum salmon *Oncorhynchus keta*, northern pike *Esox lucius*, burbot *Lota lota*, and whitefish *Family Coregonidae*. The Salcha River is accessed by car from the Richardson Highway at milepost 348. Access by car is limited to a 1.6 km area adjacent to the Salcha River State Recreation Area. Riverboat and floatplane provide much of the access to upstream areas of the Salcha River. In 1987, regulations were promulgated to protect the Arctic grayling fishery from decline. These regulations:

1) restrict the harvest of Arctic grayling to fish 305 mm (12 in) or greater in total length;

2) restrict methods of harvest to unbaited artificial lures only; and,

3) eliminate the harvest of Arctic grayling during the spawning period (1 April to the first Saturday in June).

Prior to 1977 very little data were collected from the recreational fishery. A creel survey was conducted during the summers of 1953 through 1958. Harvest was not estimated, but angler harvest rates ranged from 0.48 Arctic grayling per hour to 1.09 Arctic grayling per hour (Warner 1959b). Angler harvest rate surveys were also conducted in 1963 and 1964; harvest rates were 0.67 and 0.64 fish per hour, respectively (Roguski and Winslow 1969). The first harvest and effort survey was conducted in 1968. A total of 7,048 Arctic grayling was harvested in 7,035 angler-hours for a harvest rate of 1.00 fish per hour (Roguski and Winslow 1969). A harvest and effort survey was also conducted in 1974, with an estimated 4,728 Arctic grayling harvested in 11,284 angler-hours (Kramer 1975).

Since 1977, Mills (1979-1990) has estimated harvest and angling effort on the Salcha River through a postal survey. Annual harvest of Arctic grayling has averaged 6,367 fish, ranging from 2,383 in 1988 to 13,305 in 1984 (Table 1).

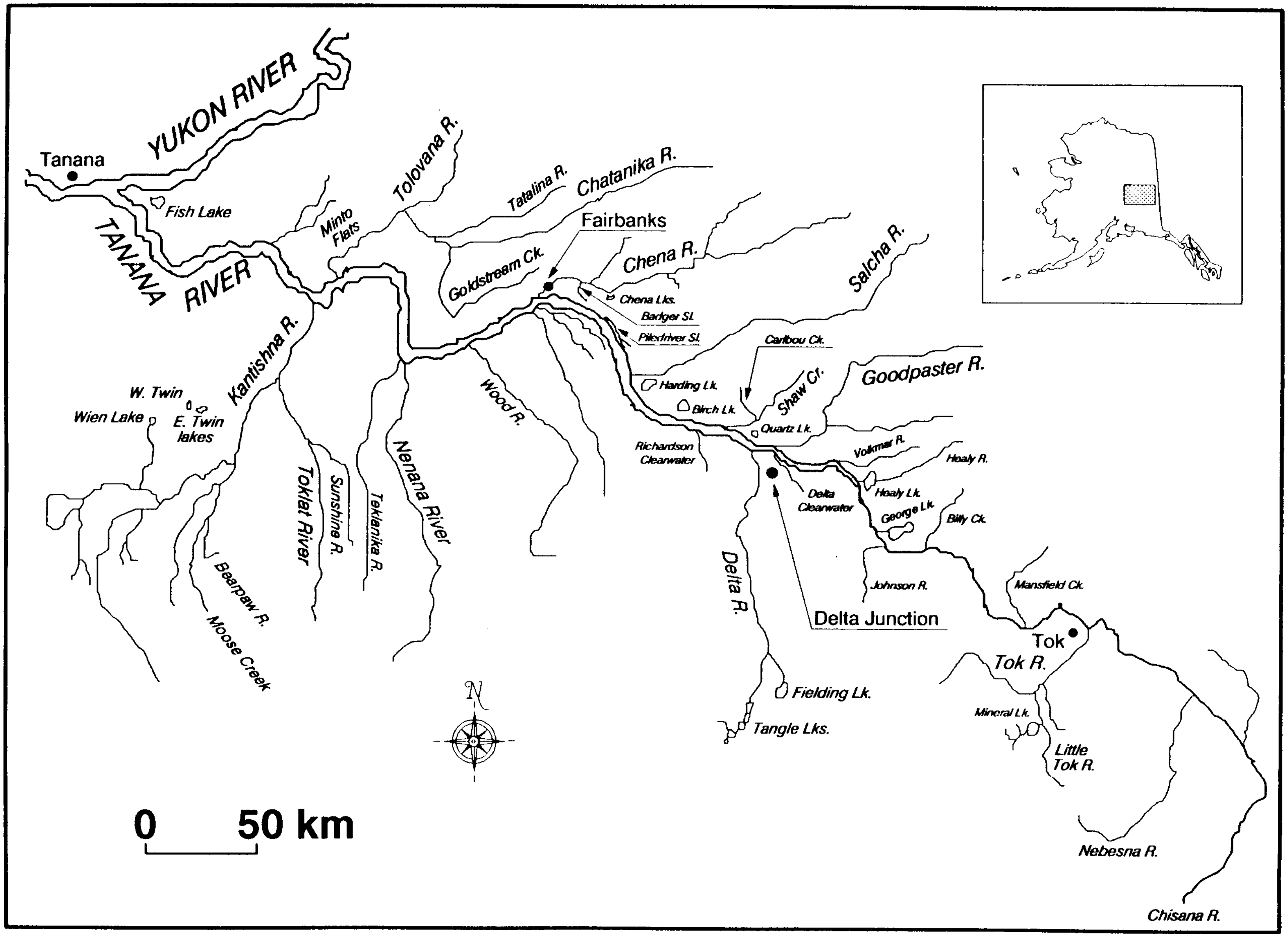

Figure 1. The Tanana River drainage.

Table 1. Recreational Arctic grayling harvest and angling effort on the Salcha, Chatanika, and Goodpaster rivers, 1977-1989[a].

Year	Salcha River Harvest[b]	Salcha River Effort[c] (angler-days)	Chatanika River Harvest	Chatanika River Effort (angler-days)	Goodpaster River Harvest	Goodpaster River Effort (angler-days)
1977	6,387	8,167	6,737	9,925	ND[d]	ND
1978	9,067	9,715	9,284	10,835	ND	ND
1979	5,980	14,788	6,121	4,853	ND	ND
1980	5,351	8,858	5,143	5,576	ND	ND
1981	3,983	8,090	3,808	4,691	ND	ND
1982	6,843	14,126	6,445	9,417	ND	ND
1983	9,640	11,802	9,766	10,757	3,021	1,989
1984	13,305	8,449	4,180	8,605	1,194	766
1985	5,826	13,109	7,404	10,231	2,757	2,844
1986	7,540	13,792	2,692	7,783	1,508	933
1987	4,762	10,576	5,619	11,065	1,702	3,061
1988[e]	2,383	7,494	8,640	11,642	1,273	1,037
1989[e]	5,721	9,704	6,934	12,210	1,964	1,930
Averages	6,676	10,667	6,367	9,045	1,917	1,794

[a] Mills (1979-1990).
[b] Harvest is the estimated number of Arctic grayling taken.
[c] Effort is the number of angler-days expended for all fish species.
[d] ND = data not available.
[e] Special regulations were in effect on the Salcha River in 1988 and 1989. These regulations are: 1. Catch and release Arctic grayling fishing from 1 April to the first Saturday in June; 2. 12 inch (305 mm) minimum length limit; and, 3. artificial lures or flies only.

Angling effort for all species of sport fish has averaged 10,667 angler-days, ranging from 7,494 angler-days in 1988 to 14,126 angler-days in 1982.

In addition to harvest data provided by Mills (1988), Baker (1988) conducted a creel survey of Salcha River anglers in 1987 (May through August). Catch rate was estimated at 0.66 (SE = 0.40) Arctic grayling harvested per angler-hour.

Chatanika River:

The Chatanika River is a runoff stream that flows southwest out of the White Mountains, draining through Minto Flats into the Tolovana River (Figure 1). Formed by the confluence of Faith and McManus creeks, the Chatanika River parallels the Steese Highway for approximately 70 km. The Chatanika River is also crossed at kilometer 18 of the Elliot Highway. Townsend (1987) described three reaches of the Chatanika River. Much of the upper reach (Long Creek to the headwaters) is accessible from the Steese highway and supports recreational fishing for Arctic grayling, three species of whitefish, and two species of Pacific salmon. The middle reach is also accessible from the Steese and Elliot highways and supports fishing for these species as well. The lower reach is accessible by riverboat from the Elliot highway and the Murphy Dome Road Extension. This reach of the Chatanika River supports northern pike, sheefish *Stenodus leucichthys*, and burbot fishing.

The Chatanika River is much more accessible than the Salcha River, mainly due to a long history of placer mining in the area. As of 1986, there were placer mining operations on portions of Faith, Sourdough, No Name, and Flat creeks of the upper Chatanika River (Townsend 1987). Townsend (1987) also reported mining activity on Goldstream Creek in the lower Chatanika. There are four recreation sites on the Chatanika River; 63-km Steese Highway campground, 18-km Elliot Highway (one campground and one picnic area), and 98-km Steese Highway campground.

Although extensive studies of the Chatanika River Arctic grayling fishery were performed before statehood (Warner 1959b), very little creel survey data were obtained prior to 1977. Angler catch rates were estimated during summer 1953-1958, ranging from 0.13 Arctic grayling per hour in 1955 to 0.78 Arctic grayling per hour in 1954 (Warner 1959b). Fishery managers during this period thought that excessive harvest of sub-adult grayling was causing declines in fish abundance and angler catch rates (Wojcik 1954, 1955). A 305 mm (12 inch) minimum length limit for Arctic grayling was enforced between 1955 and 1958, but was removed in 1959 (Warner 1959b).

A creel survey of the Chatanika River Arctic grayling fishery along the Steese Highway was conducted by Kramer (1975) in 1974. An estimated 27,250 angler-hours were expended with a catch rate of 1.02 Arctic grayling per hour. From 1977 through 1988, harvest of Arctic grayling was estimated by Mills (1979-1990). Annual harvest averaged 6,367 fish during this period, with 9,045 angler-days of effort (Table 1). Annual harvests during this period ranged from 2,692 fish in 1986 to 9,766 fish in 1983.

In addition to harvest data provided by Mills (1988), Baker (1988) conducted a creel survey of Chatanika River (Elliot highway area) anglers in 1987 (May through June). Catch rate was estimated at 0.02 Arctic grayling harvested per angler-hour.

Goodpaster River:

The Goodpaster River is a typical rapid runoff stream of interior Alaska. Draining an area of approximately 4,100 km^2, the Goodpaster River originates in the Tanana Uplands and flows southwest for 224 km to its confluence with the Tanana River, 16 km north of Delta Junction (Figure 1). The river has 13 named tributaries, the largest of which are the Eisenmenger Fork (38 km long) at river kilometer 184 and the South Fork (64 km long) at river kilometer 53.

Below the confluence of the South Fork, the river can be characterized as generally shallow (< 1 m deep) but wide (60 m across), slow moving, meandering, slightly humic stained, and susceptible to rapid fluctuations in water level. Van Whye (1964) described this reach as quite low in productivity due to little aquatic vegetation and a bottom type consisting primarily of sand. He described the river above the South Fork confluence as having a predominantly coarse gravel bottom with a high density of aquatic vegetation and food organisms.

The Goodpaster River Arctic grayling population has been included in 25 Federal Aid in Fish Restoration studies since 1955. These studies can be broken into two main categories: inter-stream migration studies from 1955 through 1966 and stock assessment studies from 1969 to the present. The migration studies presented very little data on age and size compositions of the tagged fish and instead presented quantitative data of number tagged and recovered by area. These quantitative data were partially summarized and interpreted by Reed (1961), Nagata (1963), and Roguski (1967). Generally stated, they found that the Goodpaster River served as a spawning and nursery stream for part of the summer Arctic grayling populations found in the Richardson and Delta Clearwater rivers (Figure 1). While presenting no quantitative data, Reed (1961) stated that the majority of Goodpaster fish were tagged as two and three year olds while the recoveries of these fish in the clearwater streams were at ages five and greater. He suggested an age-size relationship for inter-stream movements. Ridder (1983) summarized the recovery data from the 7,955 fish tagged in the Goodpaster River in these studies. Of the 507 recoveries, 76% were made in the Goodpaster River and 24% in other waters, predominantly the Delta and Richardson Clearwater rivers. Stock separation data from scale pattern analysis of age 3 fish showed that the Goodpaster River could be the source of, at the most, 51% of the Delta Clearwater River Arctic grayling population (Ridder 1983).

Past stock assessment studies presented data on age and size compositions, population abundance (whole river and index sections), and intra-stream movements. Data on the former two parameters are included in Appendix B. Tack (1974, 1980) found and described an upstream, pre- and post-spawning movement in late May and early June followed by a mid-summer period of little movement. During this mid-summer period, juveniles and sub-adults occupied the lower 53 km, a mix of these groups were found in the middle drainage, and adults dominated above river kilometer 98.

The recreational fishery on the Goodpaster River is primarily for Arctic grayling and is conducted from approximately 15 May through 20 September. Most anglers are summer or permanent residents of the Delta Junction area. Some anglers target northern pike and burbot. Some round whitefish *Prosopium cylindraceum* are also harvested. While the river supports a small run of chinook salmon, the fishery is closed by regulation. The river is accessible only by riverboat or airplane. Boat launches are located at Big Delta on the Tanana River and at Clearwater Lake. Riverboat access is feasible only in the lower 98 km of the river and the lower 5 km of the South Fork. Floatplane access occurs only in the lower 36 km. Landing strips are located at Central Creek at river kilometer 118 and at Tibbs Creek, a tributary of the Eisenmenger Fork. There are approximately fifty cabins on the river used by summer residents. All but five cabins are located between river kilometers 11 and 48. No summer cabins lie above Central Creek. The Fairbanks Daily News Miner (4 September 1987) reports, "More than a hundred families own property in the area and transient use has grown rapidly during the past five years."

Data on the recreational fishery in the Goodpaster River are sparse. Tack (1974) conducted an on-site creel survey program in 1973. A check station at river kilometer 1 was used to interview and count angler arrivals and departures with a stratified random sampling schedule. He estimated a harvest of 2,236 Arctic grayling with a monthly harvest rate that ranged from 0.69 to 1.63 Arctic grayling harvested per hour. He reported 241 mm FL as the mean length of the sampled harvest (n = 241), that the harvest came predominantly from the lower 53 km of the river, and that the estimated 899 angler-days of effort were mainly by residents of the area. No other data were available until the statewide harvest survey (Mills 1984-1990) began to obtain estimates of harvest and effort in 1983 (Table 1). Annual harvests since then have averaged 1,917 Arctic grayling. Effort for all species has averaged 1,794 man-days for the same period.

This report summarizes all data pertinent to stock assessment work conducted on the Goodpaster River from 1955 to 1990. These data can be found in Appendices B1 through B14.

METHODS

Estimation of Abundance

Specific methodologies have been developed to estimate abundance of Arctic grayling in runoff rivers of interior Alaska. Sampling schemes have evolved from multiple-sample mark-recapture experiments in short "index" sections (Van Hulle 1968) to single-sample experiments in relatively longer sections of river (Clark and Ridder 1987). These advances were made possible by the use of electrofishing equipment. Paradoxically, the efficiency of electrofishing is offset by its tendency for bias due to size-selectivity (Reynolds 1983). However, mark-recapture methodology can be used to correct for the inherent bias of electrofishing gear without sacrificing the efficacy of sampling programs. Much of what we have learned about abundance estimation in runoff streams is presented below.

Long study areas were chosen, in general, to minimize emigration of fish during the experiments. Collection of mark and recapture data in all three rivers was segregated by area to facilitate the estimation of fish movement within study sections. To quantify movement of fish during the experiments, each study section is divided into three study areas. The downstream and upstream areas are usually shorter than the midstream area.

Population abundance of Arctic grayling greater than 149 mm FL was estimated with mark-recapture methods (Seber 1982), which in these experiments assume:

1) the population is closed (no change in the number of Arctic grayling greater than 149 mm FL in the population during the estimation experiment);

2) all Arctic grayling have the same probability of capture during the first sample <u>or</u> in the second sample <u>or</u> marked and unmarked Arctic grayling mix randomly between the first and second samples;

3) marking of Arctic grayling does not affect their probability of capture in the second sample;

4) Arctic grayling do not lose their mark between sampling events; and,

5) all marked Arctic grayling are reported when recovered in the second sample.

Assumption 1 was not tested directly, but movement of fish out of the river section was inferred from analysis of movements of fish between the three study areas. A chi-squared goodness of fit test was performed to determine the significance of movement in the study section between areas (Evenson 1988). The test compares the proportion of fish movement observed from mark-recapture with the proportion of fish movement expected if no movement had occurred. Other factors possibly contributing to the failure of assumption 1 (mortality and growth recruitment) were assumed to be negligible. The short duration of the experiments should have prevented appreciable mortality and growth from occurring. In practice, we perform this test after testing (and adjusting if necessary) assumptions 2 and 3, as shown below.

Assumptions 2 and 3 were tested with two Kolmogorov-Smirnov two-sample statistical tests and a chi-squared contingency table test. The first test compared the length frequency distributions of recaptured Arctic grayling with those captured during the marking sample. The second test compared the length frequency distributions of Arctic grayling captured during the marking sample with those captured in the recapture sample. The results of these two tests determined the methodology used to alleviate bias in abundance estimation (see Appendix C1). The third test compared the rates of recovery (number recaptured per number released) among the three study areas in a river section. This test was performed after the two Kolmogorov-Smirnov tests, stratified by length if necessary. If recovery rates were similar among areas, then assumption 3 was met. Recovery rates among study areas are generally the same because sampling was conducted with equal effort along the entire river section (Clark 1990). Assumption 4 could be tested because double marking was employed to allow estimation of tag loss. Assumption 5 was valid because only recaptures recovered by sampling crews during the experiment (and not angler returns after the experiment) were used to estimate abundance.

If tests of assumptions 2 and 3 indicated that capture probabilities were not equal among all sizes of Arctic grayling marked, data were stratified into size classes and separate abundance estimates calculated for each data set. Size classes were chosen by maximizing the difference in capture probabilities among sizes of fish marked. Difference in capture probabilities was maximized by observing significance levels in a series of chi-squared tests. These tests compared numbers of fish marked and not seen in the second sample versus numbers of fish marked and seen in the second sample. The number of size classes used for chi-squared tests was restricted to two because further stratification could possibly reduce overall precision while gaining very little additional accuracy.

Next, the possibly stratified mark-recapture data were examined for directed movement of fish (assumption 1). If fish did not appear to migrate during the experiment, the modified Petersen estimator of Bailey (1951, 1952) was used to estimate abundance:

$$\hat{N} = \frac{M\,(C + 1)}{(R + 1)} \qquad (1)$$

where:
- M = the number of Arctic grayling marked and released alive during the first sample;
- C = the number of Arctic grayling examined for marks during the second sample;
- R = the number of Arctic grayling recaptured during the second sample; and,
- $\hat{N}$ = estimated abundance of Arctic grayling during the first sample.

Alternatively, if significant interarea movement of fish in the study section was observed between the marking (first event) and recapture (second event) samples a modified Petersen estimator (Bernard pers. comm.[1], Evenson 1988) was used to compensate for the movement of marked Arctic grayling out of the study section. The additional assumptions necessary for accurate use of this estimator are (Evenson 1988):

6) no Arctic grayling tagged in the midstream area migrate out of the study section; and,

7) a single process causes upstream movement, and a single process causes downstream movement.

[1] Bernard, David. Personal Communication. ADFG, Sport Fish Division, 333 Raspberry Road, Anchorage, AK 99518-1599.

The modified Petersen estimator that accounts for movements of tagged fish is:

$$\hat{N} = \frac{\{ M_1(1-\hat{\Theta}_d) + M_2 + M_3(1-\hat{\Theta}_u) \} \{C + 1\}}{R_{..} + 1} \qquad (2)$$

where:

M_x = the number of Arctic grayling marked in the first event in section x (x = 1, 2, and 3 for the downstream, midstream, and upstream areas, respectively);

$R_{..}$ = the number of Arctic grayling recaptured during the second event;

Θ_z = the probability that an Arctic grayling will move out of an area in the z direction (<u>u</u>pstream or <u>d</u>ownstream);

C = the catch made during the second event; and,

N = the abundance of Arctic grayling in <u>all</u> areas at the start of the second event.

The probabilities of movements are estimated by:

$$\hat{\Theta}_d = \frac{M_2(R_{32} + R_{21})}{R_{2.}(M_3 + M_2)}, \text{ and} \qquad (3)$$

$$\hat{\Theta}_u = \frac{M_2(R_{12} + R_{23})}{R_{2.}(M_1 + M_2)} \qquad (4)$$

where:

R_{xy} = the number of Arctic grayling that were marked in area x during the first event and were recaptured in area y during the second event; and,

$R_{2.}$ = the number of Arctic grayling that were marked in the midstream area during the first event and were recaptured during the second event in all areas.

Variance of these abundance estimates was calculated by bootstrapping (Efron 1982). First, capture history of each fish was recorded by study area. A capture was denoted with the study area (1 for downstream, 2 for midstream, and 3 for upstream area). If the fish was not seen, this was denoted by a zero. The total number of capture histories was the sum of fish marked in the fish event plus fish examined in the second event minus the number of fish seen in both events (recaptures). These capture histories were then resampled with replacement 1,000 times by computer. Each replication of the estimation experiment involved sampling of "the total number of capture histories" and then calculating an abundance estimate (and probabilities of movement for the modified estimator). After 1,000 replications the mean and sample variance (Snedecor and Cochran 1980) were calculated for all replicates:

$$\hat{N}_B = \frac{\sum_{i=1}^{1,000} \hat{N}_i}{1,000} \tag{5}$$

where:

$\hat{N}_B$ = the bootstrap mean of 1,000 replicates of the mark-recapture experiment;

$\hat{N}_i$ = the ith bootstrap replicate of the mark-recapture experiment; and,

$$\hat{V}[\hat{N}_B] = \frac{\sum_{i=1}^{1,000} (\hat{N}_i - \hat{N}_B)^2}{1,000 - 1} \tag{6}$$

where:

$\hat{V}[\hat{N}_B]$ = the bootstrap variance of N_B.

If stratification was necessary, abundance and variance of abundance were then estimated for all sizes of Arctic grayling by adding the independent abundance estimates and variances:

$$\hat{N} = \hat{N}_S + \hat{N}_L \quad \text{and} \tag{7}$$

$$V[\hat{N}] = V[\hat{N}_S] + V[\hat{N}_L] \tag{8}$$

where:

N = the abundance of Arctic grayling greater than 149 mm FL;

N_S = the abundance of small Arctic grayling; and,

N_L = the abundance of large Arctic grayling.

Salcha River:

Population abundance was estimated in a 36.8 km long study section of the Salcha River. The study section was bounded upstream at river km 40.0 and bounded downstream at river km 3.2 (Richardson Highway crossing; Figure 2). To quantify movements of Arctic grayling during abundance estimation, the study section was further subdivided into three study areas. The downstream, midstream and upstream areas were 9.6, 17.6, and 9.6 km long, respectively. This section of the Salcha River encompasses areas used for stock assessment in 1987 (Clark and Ridder 1988) and 1988 (Clark 1988), and is the same river section used in 1989 (Clark and Ridder 1990).

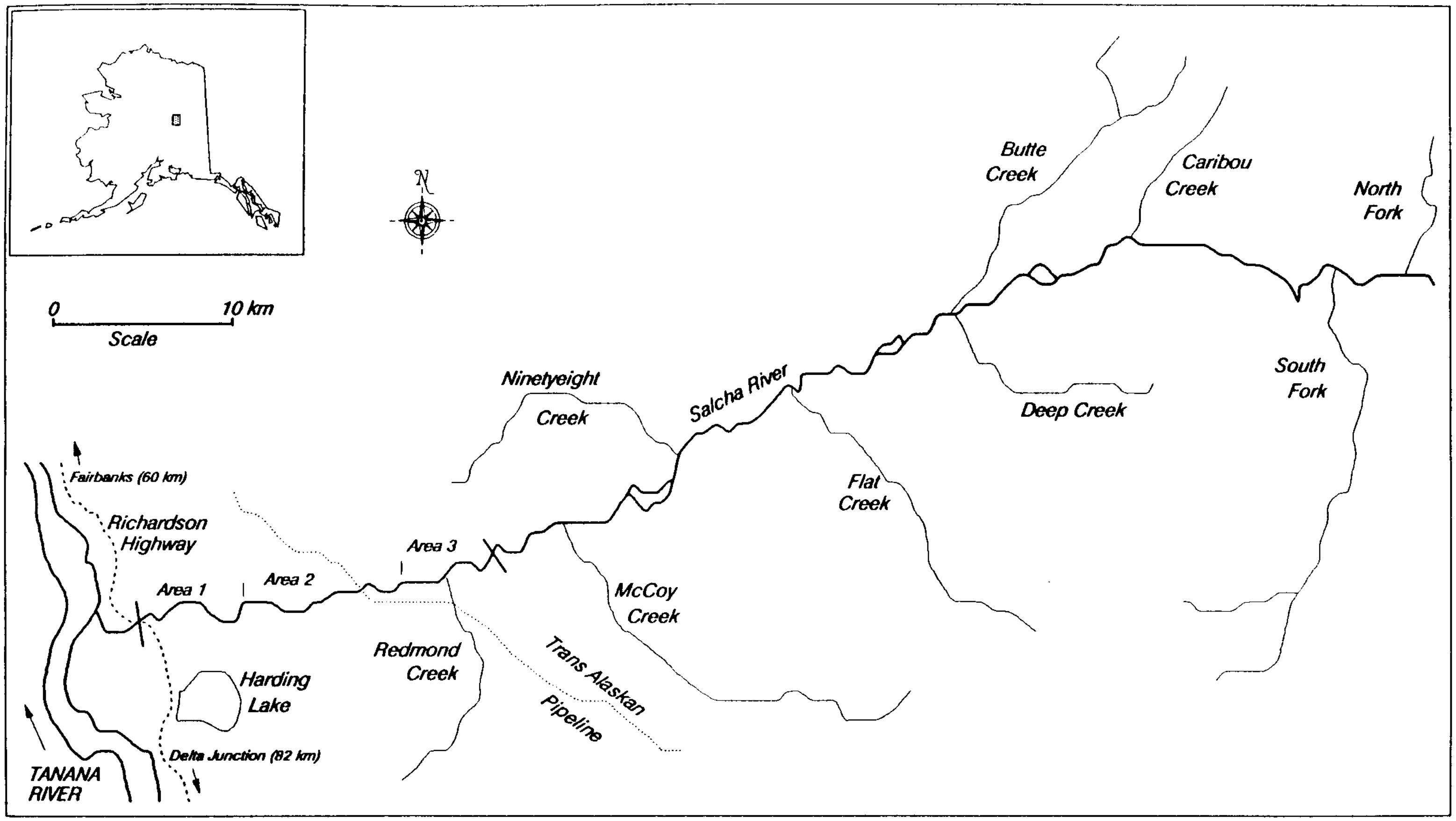

Figure 2. Study sections of the Salcha River in 1990.

Marking data were collected with a pulsed-DC electrofishing boat using a variable voltage pulsator and 10 mm diameter steel cable anodes. The unpainted bottom of the boat served as the cathode. Pulsator settings during electrofishing were: duty cycle 50%, pulse width 60 Hz, average voltage 265 VDC; and, average amperage 3.0 A. Conductivity was 135 μS (standardized to 25°C) at river kilometer 40 at the start of the experiment. Water temperature was 11.5°C at the time of the conductivity measurement. Water level was low and water clarity was excellent during the estimation experiment. Recapture data were collected with two electrofishing boats of similar design and operating characteristics.

The marking event occurred on 19 through 23 June and the recapture event on 26 and 27 June. Events started at the upstream end of the river section. Sampling consisted of electrofishing along each bank to collect as many fish as possible. Each sampling event was divided into 20 minute-long runs. Sampling both banks (along approximately 2 km of river) required two runs. After both banks were sampled, fish greater than 149 mm fork length (FL) were measured to the nearest 1 mm FL, tagged with a uniquely numbered Floy FD-67 internal anchor tag, fin clipped (right ventral fin), and released. The right ventral fin was removed to allow determination of mark status if a tag was shed. The use of 20 minute-long runs allowed for even distribution of marked fish in the study section and accurate determination of the area of release.

Chatanika River:

Population abundance was estimated in a 28.8 km section of the Chatanika River. The study section was bounded 7.5 km upstream of the Elliot Highway crossing and 21.3 km downstream of the highway crossing (Figure 3). To quantify movements of Arctic grayling during abundance estimation, the study section was further subdivided into three study areas. The downstream, midstream and upstream areas were 6.8, 15.2, and 6.8 km long, respectively. This section of the Chatanika River encompasses areas used for stock assessment in 1972 (Tack 1973), 1982 (Holmes 1983), and 1984 through 1985 (Holmes 1985 and Holmes, et al. 1986).

Marking data were collected with a pulsed-DC electrofishing boat using a variable voltage pulsator and 12 mm diameter aluminum conduit anodes. The unpainted bottom of the boat served as the cathode. Pulsator settings during electrofishing were: duty cycle 50%, pulse width 60 Hz, average voltage 280 VDC; and, average amperage 3.0 A. Conductivity was 55 μS (standardized to 25°C) at the start of the experiment. Water temperature was 7.5°C at the time of the conductivity measurement. Water level was high and water clarity was low during the estimation experiment. Recapture data were collected with two electrofishing boats of similar design and operating characteristics.

The marking event occurred on 27 through 30 August and the recapture event on 6 and 7 September. Events started at the upstream end of the river section. Sampling consisted of electrofishing along each bank to collect as many fish as possible. Each sampling event was divided into 20 minute-long runs. Sampling both banks (along approximately 2 km of river) required only one run because the river is narrow in this section (~10-15 m wide). After both banks were sampled, fish greater than 149 mm fork length (FL) were measured to the

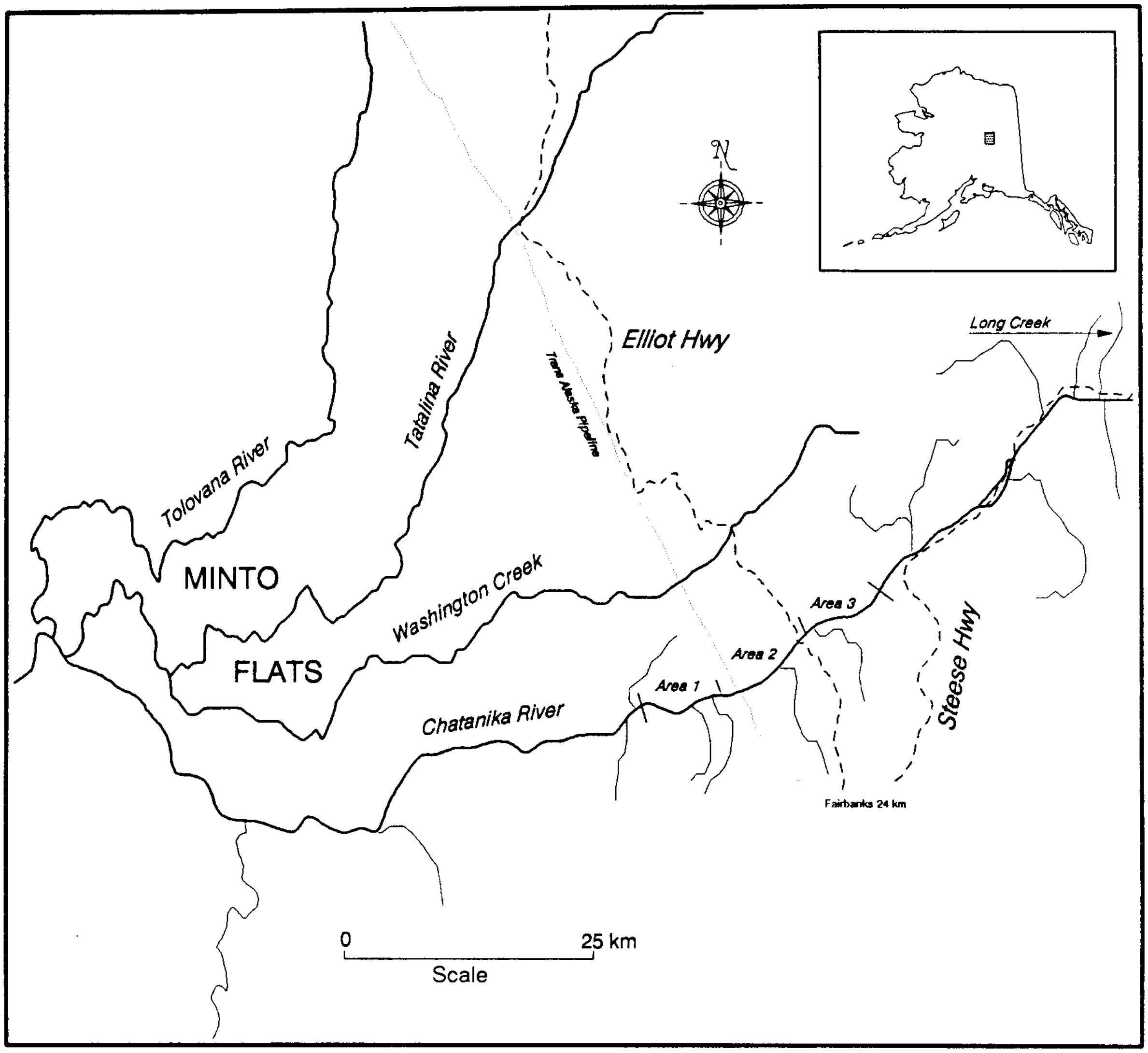

Figure 3. Study sections of the Chatanika River in 1990.

nearest 1 mm FL, tagged with a uniquely numbered Floy FD-67 internal anchor tag, fin clipped (right ventral fin), and released. The right ventral fin was removed to allow determination of mark status if a tag was shed. The use of 20 minute-long runs allowed for even distribution of marked fish in the study section and accurate determination of the area of release.

Goodpaster River:

Population abundance was estimated in a 50 km section of the lower Goodpaster River. The upstream boundary of the study section is at river kilometer 52.3 (the confluence of the South Fork of the Goodpaster River) while the lower boundary is at river kilometer 2.7 (Figure 4). While the lower, or main, mouth of the river was to be the lower boundary, high flows in the glacial Tanana River backed up the river 2.7 km producing high turbidity and ineffective electrofishing. The study section was further subdivided into three study areas. Area 1 was 16.5 km long and extended from the downstream boundary to approximately river kilometer 19.2. Area 2 was 14.4 km long and extended to river kilometer 33.6. Area 3, the upstream section, was 18.7 km long. These study areas are similar to those used in 1988 (Ridder 1989) and 1989 (Clark and Ridder 1990).

Samples were taken during two events, each three days long and each beginning at study area 3 and progressing downstream. The marking event ran from 8 to 10 August and the recapture event ran from 14 to 16 August. One study area in the river section was sampled each day. The time interval between sampling events for each of the three study areas was six days. Sampling started at the upstream end of an area and consisted of two electrofishing boats traveling downstream, one along each bank, collecting as many Arctic grayling as possible in a 20 minute interval. After both banks were sampled, fish greater than 149 mm fork length (FL) were measured to the nearest 1 mm FL, tagged with a uniquely numbered Floy FD-67 internal anchor tag, fin clipped (partial right pectoral fin), and released. The right pectoral fin was partially removed to allow determination of mark status if a tag was shed. The use of 20 minute-long runs allowed for even distribution of marked fish in the study section and accurate determination of the area of release.

Each electrofishing boat had a crew of two "dippers" and a driver, and each boat was equipped with a pulsed DC variable voltage pulsator (Coffelt Model VVP-15) powered by a 3,500 W single-phase gasoline generator. Anodes were four 10 mm diameter steel cables 1.5 m long arranged perpendicular to the long axis of the boat and 2.1 m forward of the bow. The unpainted bottom of the aluminum boat was the cathode. Output voltage ranged from 280 to 350 VDC and output current ranged from 2 to 4 amperes. Duty cycle and pulse rate were held constant at 50% and 60 Hz, respectively. Mid-day water temperatures during the experiment ranged from 11.0 to 17.2°C. Conductivity was 140 μS (standardized to 25°C) at the start of the estimation experiment. Water level was moderately high and water clarity was slightly muddy during the marking event, while water level was receding and clarity improved during the recapture event.

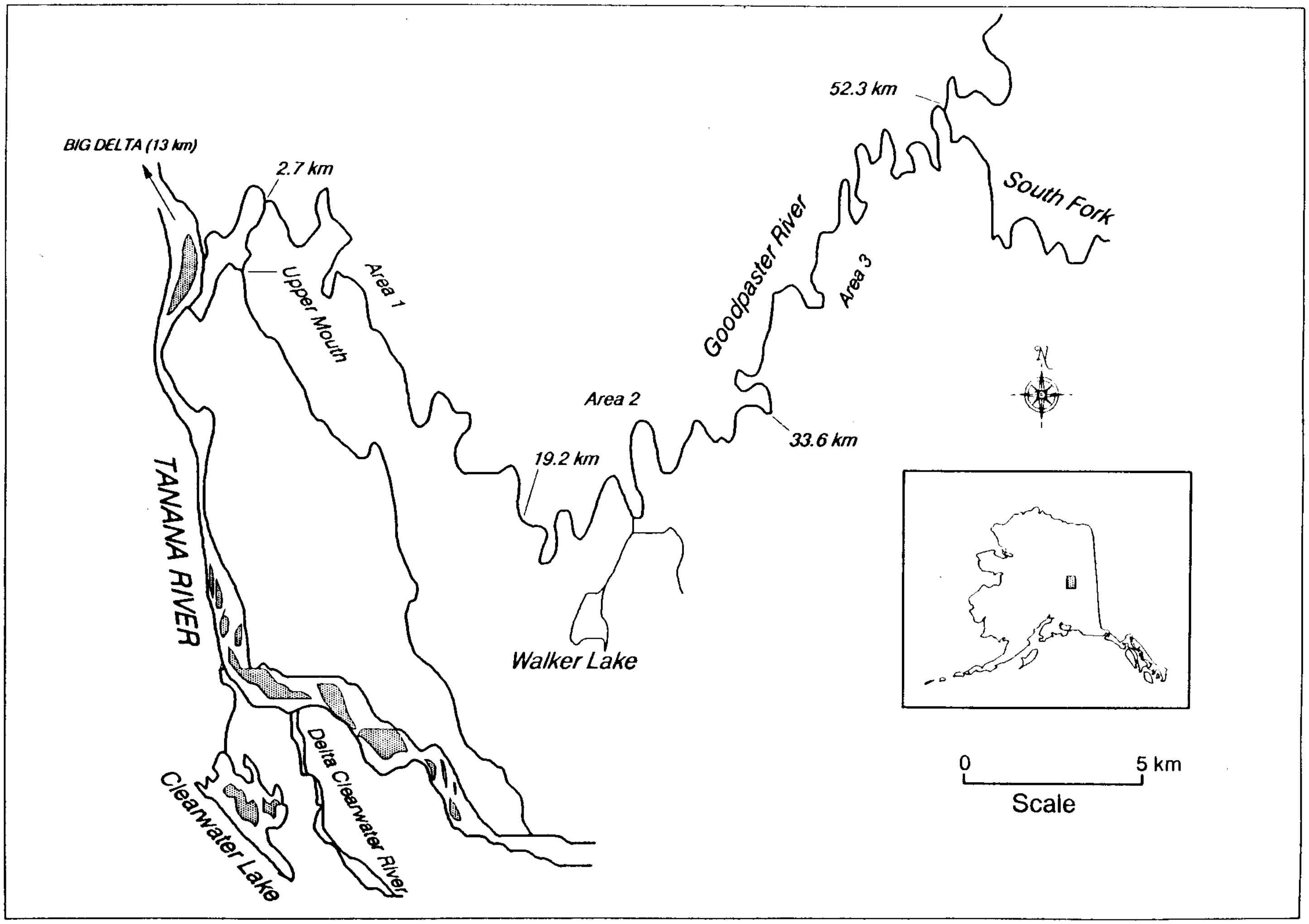

Figure 4. Study sections of the Goodpaster River in 1990.

Estimation of Age and Size Composition

Estimates of age and size composition are used to characterize the structure of Arctic grayling stocks in the Tanana drainage. Changes in age and size composition often indicate serious fishery or environmental effects on recruitment and survival. When population abundance estimates are not possible or not cost effective, these indices of stock structure can help managers to compare the health of fishery stocks.

Salcha River:

Age and size data were collected during both sampling events of the mark-recapture experiment, between 19 and 27 June. A sample of scales was taken from the preferred zone[2] of each newly captured fish. Two scales from each fish were processed by cleaning in a solution of hydrolytic enzyme and then mounted on gum cards. These gum cards were used to make impressions of the scales on triacetate film (30 seconds at 137,895 kPa, at a temperature of 97°C). Ages were determined by counting annuli on these impressions with the aid of a microfiche reader. Determination of age was performed only once for each readable set of scales.

The accuracy of age and size composition estimates are dependent on the selectivity of the sampling gear. The pulsed-DC electrofishing boat used to collect these data and has been shown to exhibit bias in capturing all sizes of Arctic grayling greater than 149 mm FL (Clark and Ridder 1988). However, the Salcha River mark-recapture data did not indicate a significant change in capture probability of marked Arctic grayling during the experiment. Therefore, age and size samples taken with the electrofishing boat were most likely similar to the true age and size composition of the Salcha River stock at the time these samples were taken. Age composition was then estimated by the proportion:

$$\hat{p}_k = \frac{x_k}{n} \qquad (9)$$

where: $\hat{p}_k$ = the proportion of Arctic grayling that are age k;
x_k = the number of Arctic grayling sampled that are age k; and,
n = the number of Arctic grayling sampled that were aged.

Variance of this proportion was estimated with the binomial:

$$V[\hat{p}_k] = \frac{p_k\ (1 - p_k)}{n - 1}. \qquad (10)$$

Size composition of the Salcha River stock was described with the incremental Relative Stock Density (RSD) indices of Gabelhouse (1984). The RSD categories

---

[2] The preferred zone for Arctic grayling is centered approximately six scale rows above the lateral line just posterior to the insertion of the dorsal fin.

for Arctic grayling are: "stock" (150 to 269 mm FL); "quality" (270 to 339 mm FL); "preferred" (340 to 449 mm FL); "memorable" (450 to 559 mm FL); and "trophy" (greater than 559 mm FL). Equations 9 and 10 were used to estimate the proportion of fish in each RSD category and the variance of these proportions.

Chatanika River:

Age and size data were collected during both sampling events of the mark-recapture experiment, between 27 August and 7 September. Data collection procedures were identical to the Salcha River study. However, the Chatanika River mark-recapture data did show a significant change in capture probability of marked Arctic grayling during the abundance estimation experiment. Therefore, age and size samples taken with the electrofishing boat were most likely different than the true age and size composition of the Chatanika River stock at the time the samples were taken. The same size class strata used for abundance estimation were used to estimate adjustment factors for age and size composition estimates.

To compensate for bias introduced by electrofishing, recapture to mark ratios were used to adjust for differential capture probability by size of fish:

$$\hat{\rho}_l = \frac{RECAP_l}{MARK_l} \qquad (11)$$

where: $\hat{\rho}_l$ = the capture probability of Arctic grayling in size class l, regardless of age k;
$RECAP_l$ = the number of recaptures of Arctic grayling in size class l; and,
$MARK_l$ = the number of marked Arctic grayling in size class l.

From the ratio of the largest capture probability to the capture probability in size class l, an adjustment to the number sampled at age k that were also of size class l was estimated (ignoring the hat symbols of ρ):

$$\hat{A}_l = \frac{\rho_L}{\rho_l} \qquad (12)$$

where: $\hat{A}_l$ = the adjustment factor for all Arctic grayling of size class l, regardless of age class k; and,
$\rho_L = \max(\rho_l)$, $l = 1, 2, \ldots, m$ size classes.

The adjustment factor was multiplied by the number of Arctic grayling sampled at age *k* that were also in size class *l*:

$$\hat{x}_{kl} = \hat{A}_l \, n_{kl} \tag{13}$$

where: $\hat{x}_{kl}$ = the adjusted number of Arctic grayling of age *k* that are also in size class *l*; and,

n_{kl} = the actual number of Arctic grayling sampled that are age *k* and also in size class *l*.

The proportion of Arctic grayling that are age *k* then re-evaluated to:

$$\hat{p}_k = \frac{\sum_{l=1}^{m} \hat{x}_{kl}}{\sum_{k=1}^{o} \sum_{l=1}^{m} \hat{x}_{kl}} = \frac{\hat{x}_{k.}}{\hat{x}_{..}} \tag{14}$$

where: k = 1, 2, ..., *o* age classes; and,
l = 1, 2, ..., *m* size classes.

The variances of these adjusted proportions were estimated by bootstrapping recapture to mark ratios 1,000 times in samples of "the number of capture histories".

To estimate the proportion of fish in each RSD category, the adjustment factors used to estimate age composition were also used to adjust bias RSD estimates. Adjustment is accomplished by replacing the number sampled at age *k* that were also in size class *l* (n_{kl}) with the number sampled in RSD category *k* = 1, 2, ..., 5 that were also in size class *l* (equations 11 through 14). Variance was estimated in an identical fashion to variance of proportion at age, bootstrapping the recapture histories of all fish 1,000 times.

Goodpaster River:

Age class compositions and RSD indices of Arctic grayling in the lower 50 km of the Goodpaster River were adjusted for bias due to size selectivity of the electrofishing gear. The adjustment procedure and formulae are identical to procedures used for the Chatanika River data (equations 11 through 14).

RESULTS

Salcha River

A total of 1,026 Arctic grayling (≥ 150 mm FL) was captured during the mark-recapture experiment. Twenty mortalities or serious injuries were recorded for an overall immediate mortality rate of 1.9%.

During 19 through 22 June, 495 Arctic grayling ($\geq$ 150 mm FL) were marked along the 36.8 km section of the Salcha River. During 26 and 27 June, 500 Arctic grayling were examined for marks along the same 36.8 km section of river. A total of 40 Arctic grayling was recaptured during the second sample. The cumulative distribution function (CDF) of lengths of marked Arctic grayling was marginally different than the CDF of lengths of recaptured Arctic grayling (*DN*[3] = 0.19, P = 0.12; Figure 5A). Therefore, the second sample was unbiased with respect to equal probability of capture of marked Arctic grayling by size. In addition, capture probabilities were not significantly different among the three areas (χ^2 = 0.03, df = 2, P > 0.5).

When tested for interarea movement of Arctic grayling between sampling events, significant movement was detected (χ^2 = 6.5, df = 1, 0.025 < P < 0.01; Table 2). Abundance of Arctic grayling, using the modified Petersen estimator of Bernard, was 5,792 fish (SE = 659 fish, CV = 11%; Table 3). Probabilities of movement were 13% (SE = 6%, CV = 48%) for downstream and 7% (SE = 3%, CV = 39%) for upstream (Table 3).

The CDF of lengths of marked Arctic grayling was significantly different than the CDF of lengths of Arctic grayling examined for marks (*DN* = 0.13, P < 0.01; Figure 5B). Therefore, age and size samples taken during the second event only were used to calculate age and size composition (Appendix C1). The two most prevalent age-classes in the study section were age 2 and age 3 fish. Age 3 Arctic grayling accounted for 37% of the estimated abundance, while age 2 Arctic grayling accounted for 22% of the stock (Table 4). Age 4 and age 5 Arctic grayling were next most abundant, accounting for 19% and 9% of the estimated abundance, respectively.

Size composition of Arctic grayling in the study section was weighted heavily towards stock size fish, accounting for 73% of the estimated abundance (Table 5). Of the fish greater than 269 mm FL, 19% were quality size, 8% were preferred size, and none were memorable or trophy size.

Chatanika River

A total of 1,621 Arctic grayling ($\geq$ 150 mm FL) was captured during the mark-recapture experiment. Nine mortalities or serious injuries were recorded for an overall immediate mortality rate of 0.6%.

During 27 through 30 August, 857 Arctic grayling ($\geq$ 150 mm FL) were marked along the 28.8 km section of the Chatanika River. During 6 and 7 September, 717 Arctic grayling were examined for marks along the same 28.8 km section of river. A total of 36 Arctic grayling was recaptured during the second sample. The cumulative distribution function (CDF) of lengths of marked Arctic grayling was significantly different than the CDF of lengths of recaptured Arctic grayling (*DN* = 0.27, P = 0.01; Figure 6A). Therefore, the second sample was biased with respect to equal probability of capture of marked Arctic grayling by size. The mark-recapture data were stratified by size into

[3] *DN* = test statistic for the Kolmogorov-Smirnov test.

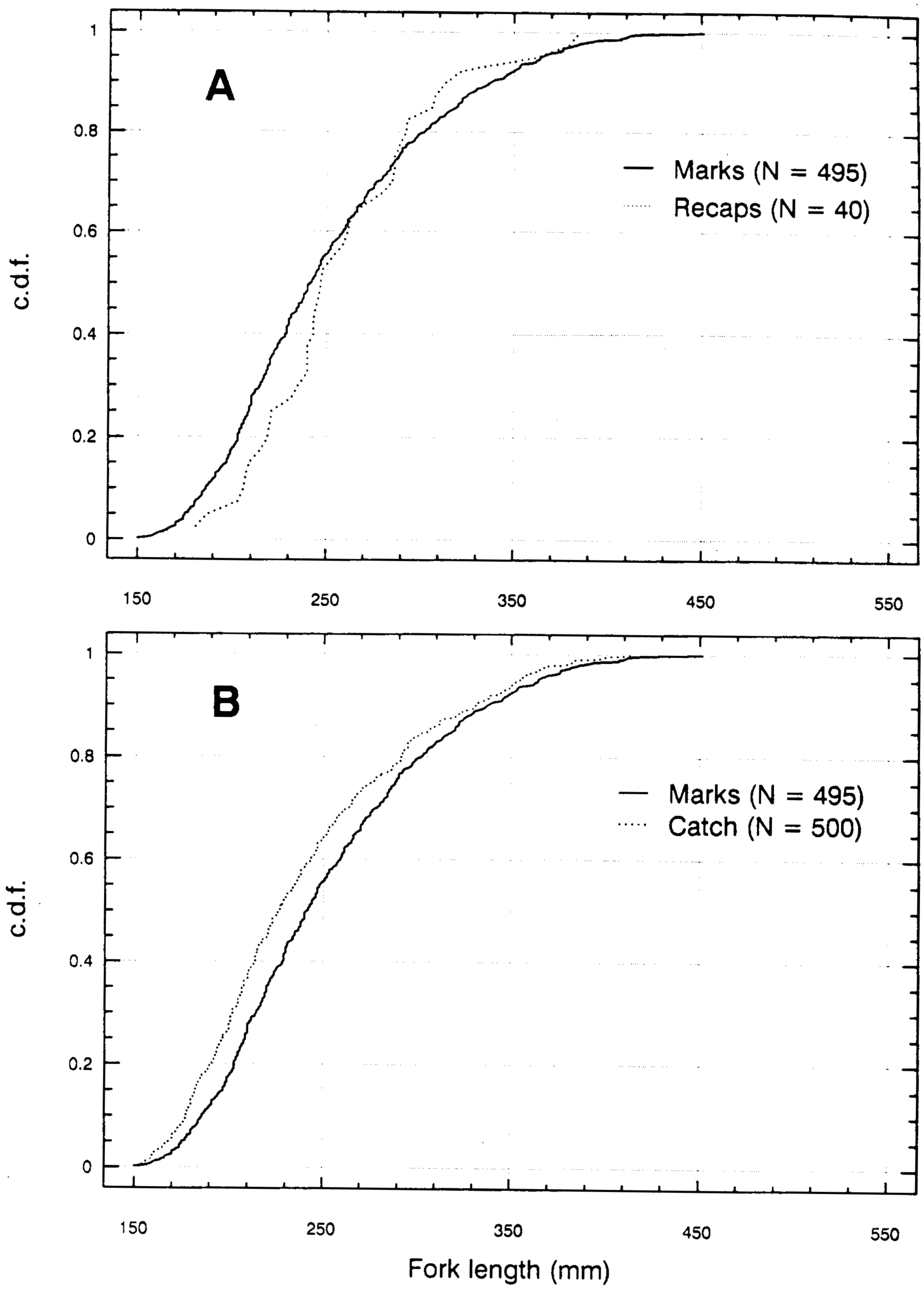

Figure 5. Cumulative distribution functions of lengths of Arctic grayling marked versus lengths of Arctic grayling recaptured (A) and versus lengths of Arctic grayling examined for marks (B) for a 36.8 km section of the Salcha River, 19 through 27 June, 1990.

Table 2. Summary of inter-section and inter-run[a] movements of Arctic grayling (≥ 150 mm FL) based on recaptures (R) in the lower 36.8 km of the Salcha River, 19 through 27 June, 1990.

Mark	Recapture																			
	Upstream Sect. 3				Midstream Sect. 2							Downstream Sect. 1								
Run #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	R_{NM}[b]	R_M[c]	Total R	Total M	R/M Ratio
1	1															1	0	1	26	0.038
2		0	2													0	2	2	45	0.044
3			7	1												7	1	8	46	0.174
4	1			0												0	1	1 (12)	36 (153)	0.028 (0.078)
5					0											0	0	0	26	0.000
6						2	1	1								2	2	4	43	0.093
7						1	0		1							0	2	2	24	0.083
8								2	3							2	3	5	44	0.114
9									1	1						1	1	2	24	0.083
10										1	1					1	1	2	28	0.071
11											0	3	1			0	4	4 (19)	40 (229)	0.100 (0.083)
12										1		1	3	1	1	1	6	7	53	0.132
13													0		1	0	1	1	18	0.055
14						1								0		0	1	1	31	0.032
15															0	0	0	0 (9)	11 (113)	0.000 (0.080)

[a] Locations are broken into river sections (see Methods) and run number. A run is approximately 2.4 km long, the distance covered by a 20 minute downstream pass of an electrofishing boat. Run 1 starts at river km 40.0 and run 15 ends at river km 3.2.

[b] R_{NM} = Fish recaptured in same run as marked.

[c] R_M = Fish recaptured either up or downstream of marking location.

Table 3. Population abundance estimate of Arctic grayling (≥ 150 mm FL) in the lower 36.8 km (23 mile) of the Salcha River, 19 through 27 June, 1990.

Parameter[a]	Calculated or Known Quantity	Bootstrap Estimate[b]
M_1	113	113
M_2	229	229
M_3	153	153
C	500	500
$R_{..}$	40	40
R_{11}	7	7
R_{12}	2	2
R_{13}	0	0
R_{21}	4	4
R_{22}	15	15
R_{23}	0	0
$R_{2.}$	19	19
R_{31}	0	0
R_{32}	0	0
R_{33}	12	12
Θ_d	0.13	0.13
SE	Unknown	0.06
Θ_u	0.07	0.07
SE	Unknown	0.03
$\hat{N}$ (Evenson 1988)	5,743	5,792
SE	Unknown	659
$\hat{N}$ (Bailey 1951, 1952)	6,048	6,131
SE	894	732

[a] Parameter definitions are: M_x (x = 1, 2, 3) = the number of Arctic grayling marked during the first event in the downstream (1), midstream (2), and upstream (3) areas; C = the number of Arctic grayling examined for marks during the second event (regardless of area); R_{xy} (x and y = 1, 2, 3) = the number of marked Arctic grayling recovered during the second event that were released in area x during the first event and recovered in area y during the second event (an ellipsis denotes all areas summed); and, Θ_x = the probability of downstream (d) or upstream (u) movement between sampling events.

[b] Number of bootstrap replications was 1,000.

Table 4. Estimates of age class composition and standard error for Arctic grayling ($\geq$ 150 mm FL) captured from the Salcha and Chatanika River stocks, 1990.

	Salcha River[a]				Chatanika River[a]			
Age Class	n[b]	p[c]	SE[d]	CV[e]	n	p[f]	SE	CV
2	45	0.22	0.03	13	126	0.20	0.02	8
3	76	0.37	0.03	9	347	0.55	0.02	4
4	38	0.19	0.03	14	80	0.11	0.01	11
5	18	0.09	0.02	22	45	0.04	0.01	20
6	13	0.06	0.02	26	51	0.04	0.01	22
7	7	0.03	0.01	38	57	0.04	0.01	24
8	5	0.02	0.01	44	17	0.01	<0.01	32
9	1	<0.01	<0.01	100	11	0.01	<0.01	37
10	0	0	0	0	2	<0.01	<0.01	74
Totals	203	1.00	---	---	736	1.00	---	---

[a] Arctic grayling were sampled from the Salcha River between 19 and 27 June, 1990. Arctic grayling were sampled from the Chatanika River between 27 August and 7 September, 1990.
[b] n = sample size.
[c] p = proportion of Arctic grayling in the population.
[d] SE = standard error of p.
[e] CV = coefficient of variation of p expressed as a percentage.
[f] p = the adjusted proportion of Arctic grayling in the population. Age composition was adjusted for size selectivity (Clark and Ridder 1990).

Table 5. Summary of Relative Stock Density (RSD) indices for Arctic grayling (≥ 150 mm FL) in the Salcha, Chatanika, and Goodpaster rivers, 1990[a].

	RSD Category[b]				
	Stock	Quality	Preferred	Memorable	Trophy
Salcha River					
Number sampled	365	95	40	0	0
Sample RSD	0.73	0.19	0.08	---	---
Standard Error	0.02	0.02	0.01	---	---
CV (%)	3	9	15	---	---
Chatanika River					
Number sampled	1,201	309	19	0	0
RSD	0.79	0.20	0.01	---	---
Adjusted RSD[c]	0.90	0.09	0.01	---	---
Standard Error	0.02	0.02	<0.01	---	---
CV (%)	2	22	31	---	---
Goodpaster River					
Number sampled	1,234	244	46	0	0
RSD	0.81	0.16	0.03	---	---
Adjusted RSD[c]	0.84	0.14	0.02	---	---
Standard Error	0.02	0.02	<0.01	---	---
CV (%)	3	13	19	---	---

[a] Arctic grayling were sampled from the Salcha River between 19 and 27 June, 1990. Arctic grayling were sampled from the Chatanika River between 27 August and 7 September, 1990. Arctic grayling were sampled from the Goodpaster River between 8 and 16 August, 1990.

[b] Minimum lengths for RSD categories are (Gabelhouse 1984):
- Stock - 150 mm FL;
- Quality - 270 mm FL;
- Preferred - 340 mm FL;
- Memorable - 450 mm FL; and,
- Trophy - 560 mm FL.

[c] Adjusted RSD is determined from methods in Clark and Ridder (1990).

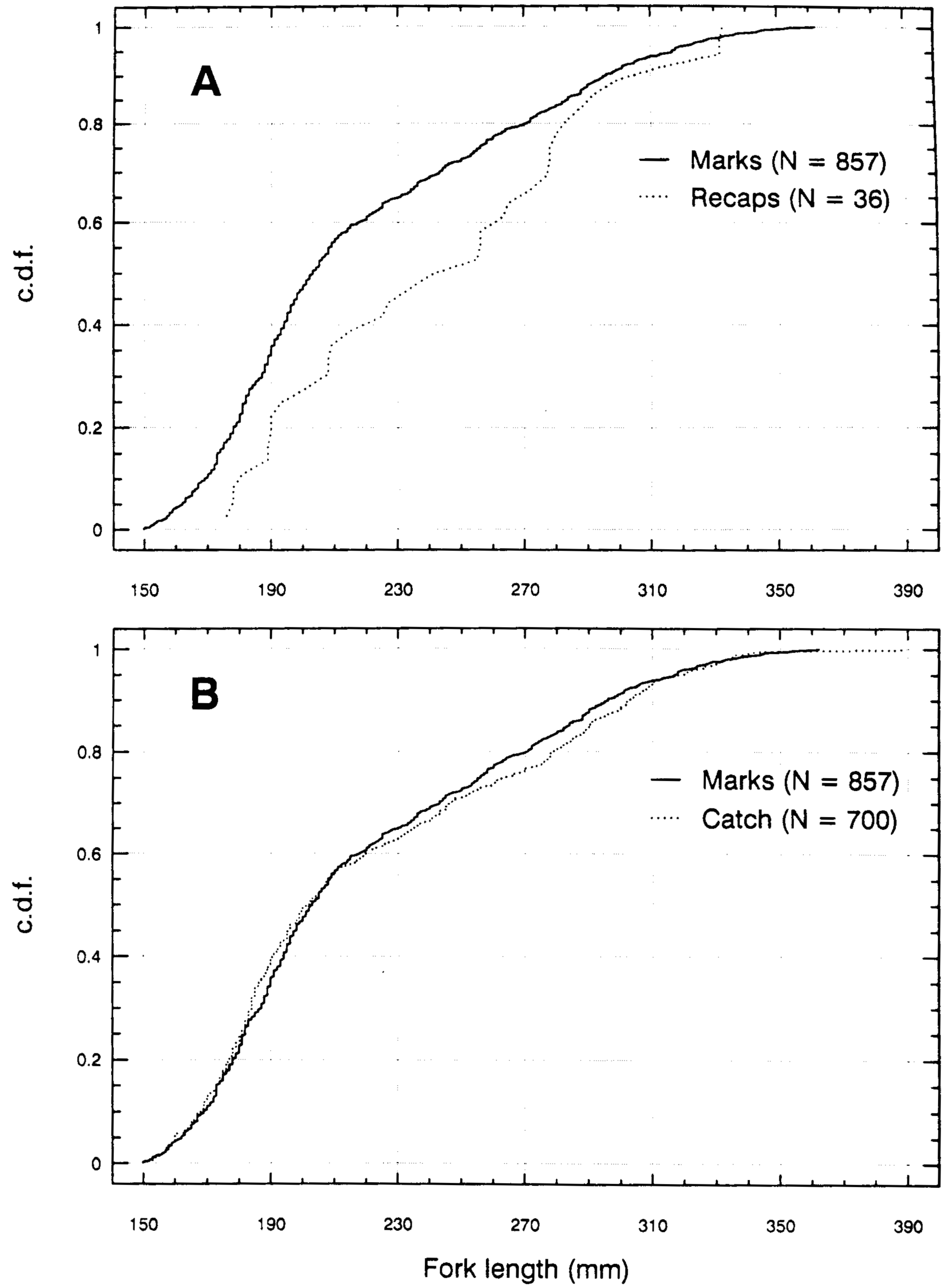

Figure 6. Cumulative distribution functions of lengths of Arctic grayling marked versus lengths of Arctic grayling recaptured (A) and versus lengths of Arctic grayling examined for marks (B) for a 28.8 km section of the Chatanika River, 27 August through 7 September, 1990.

two categories: small Arctic grayling (150 to 254 mm FL), and large Arctic grayling (greater than 254 mm FL).

When tested for interarea movement of Arctic grayling between sampling events, small Arctic grayling exhibited marginally significant movement ($\chi^2 = 3.3$, $df = 1$, $0.05 < P < 0.1$; Table 6), while large fish exhibited no movement whatsoever ($\chi^2 = 0$, $df = 1$, $P = 1$). Neither of the two size categories exhibited significant differences in capture probability by study area ($\chi^2 = 1.9$, $df = 2$, $0.1 < P < 0.5$ for small fish; and, $\chi^2 = 1.8$, $df = 2$, $0.1 < P < 0.5$ for large fish). Abundance of small Arctic grayling, using the modified Petersen estimator of Bernard, was 16,932 fish (SE = 3,173 fish, CV = 19%; Table 7). Probabilities of movement were 21% (SE = 13%, CV = 63%) for downstream and 0% for upstream (Table 7). Abundance of large Arctic grayling, using the modified Petersen estimator of Bailey, was 2,374 fish (SE = 394 fish, CV = 17%). The summed estimate of abundance of all (≥ 150 mm FL) Arctic grayling was 19,306 fish (SE = 3,197 fish, CV = 16.6%).

The CDF of lengths of marked Arctic grayling was not significantly different than the CDF of lengths of Arctic grayling examined for marks ($DN = 0.05$, $P = 0.26$; Figure 6B). Therefore, age and size samples taken during the first and second events were pooled and used to calculate age and size composition (Appendix C1). The two most prevalent age-classes in the study section were age 2 and age 3 fish. Age 3 Arctic grayling accounted for 55% of the estimated abundance, while age 2 Arctic grayling accounted for 20% of the stock (Table 4). Age 4 Arctic grayling were next most abundant, accounting for 11% of the estimated abundance.

Size composition of Arctic grayling in the study section was weighted heavily towards stock size fish, accounting for 90% of the estimated abundance (Table 5). Of the fish greater than 269 mm FL, 9% were quality size, 1% were preferred size, and none were memorable or trophy size.

Goodpaster River

A total of 1,623 Arctic grayling (≥ 150 mm FL) was captured and utilized in the mark-recapture experiment. During the marking event, from 8 to 10 August, 1,051 Arctic grayling were marked and released in the study section. Following a one week hiatus, 554 fish were examined for marks, 82 of which were recaptures. During the course of this experiment 18 fish were killed and removed from the study, resulting in an overall mortality rate of 1.1%.

The comparison of CDF's of length from the mark and recapture samples resulted in no significant difference in capture probability ($DN = 0.14$, $P = 0.10$). However, a functional difference was discerned from plots of the two CDF's (Figure 7A). As a result, the mark-recapture data were stratified into small Arctic grayling (150 to 215 mm FL) and large Arctic grayling (greater than 215 mm FL) to investigate the extent of bias that was not statistically detected. In addition, capture probabilities were not significantly different among the three areas ($\chi^2 = 2.3$, $df = 2$, $0.10 < P < 0.50$).

Although movements of several marked fish were of considerable magnitude (Table 8), the balance of movements between sampling events was small. No

Table 6. Summary of inter-section and inter-run[a] movements of small (150 to 254 mm FL) Arctic grayling based on recaptures (R) in a 28.8 km section of the Chatanika River, 27 August through 7 September, 1990.

Mark	Recapture																					
	Upstream Sect. 3			Midstream Sect. 2									Downstream Sect. 1									
Run #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	R_{NM}[b]	R_M[c]	Total R	Total M	R/M Ratio
1	0	2																0	2	2	32	0.063
2		1																1	0	1	65	0.015
3			1	2	1													1	3	4 (7)	63 (160)	0.063
4				1	1													1	1	2	57	0.035
5					2													2	0	2	51	0.039
6						1												1	0	1	26	0.038
7							0											0	0	0	44	0.000
8								0				1						0	0	0	44	0.000
9									0		1							0	1	1	48	0.021
10										0	1							0	1	1	23	0.043
11											3							3	0	3	13	0.231
12												0						0	0	0 (11)	35 (341)	0.000
13													0					0	0	0	28	0.000
14														0				0	0	0	43	0.000
15															0			0	0	0	19	0.000
16																0		0	0	0	17	0.000
17																	0	0	0	0 (0)	7 (114)	0.000

[a] Locations are broken into river sections (see Methods) and run number. A run is approximately 2.4 km long, the distance covered by a 20 minute downstream pass of an electrofishing boat.

[b] R_{NM} = Fish recaptured in same run as marked.

[c] R_M = Fish recaptured either up or downstream of marking location.

Table 7. Population abundance estimate of small Arctic grayling (150 through 254 mm FL) in a 28.8 km (18 mile) section of the Chatanika River, 27 August through 7 Septemeber, 1990.

Parameter[a]	Calculated or Known Quantity	Bootstrap Estimate[b]
M_1	160	160
M_2	358	358
M_3	114	114
C	516	516
$R_{..}$	18	18
R_{11}	0	0
R_{12}	0	0
R_{13}	0	0
R_{21}	0	0
R_{22}	11	11
R_{23}	0	0
$R_{2.}$	11	11
R_{31}	0	0
R_{32}	3	3
R_{33}	4	4
θ_d	0.21	0.21
SE	Unknown	0.13
θ_u	0	0
SE	0	0
$\hat{N}$ (Evenson 1988)	16,296	16,932
SE	Unknown	3,173
$\hat{N}$ (Bailey 1951, 1952)	17,434	17,853
SE	3,826	2,858

[a] Parameter definitions are: M_x (x = 1, 2, 3) = the number of Arctic grayling marked during the first event in the downstream (1), midstream (2), and upstream (3) areas; C = the number of Arctic grayling examined for marks during the second event (regardless of area); R_{xy} (x and y = 1, 2, 3) = the number of marked Arctic grayling recovered during the second event that were released in area x during the first event and recovered in area y during the second event (an ellipsis denotes all areas summed); and, θ_x = the probability of downstream (d) or upstream (u) movement between sampling events.

[b] Number of bootstrap replications was 1,000.

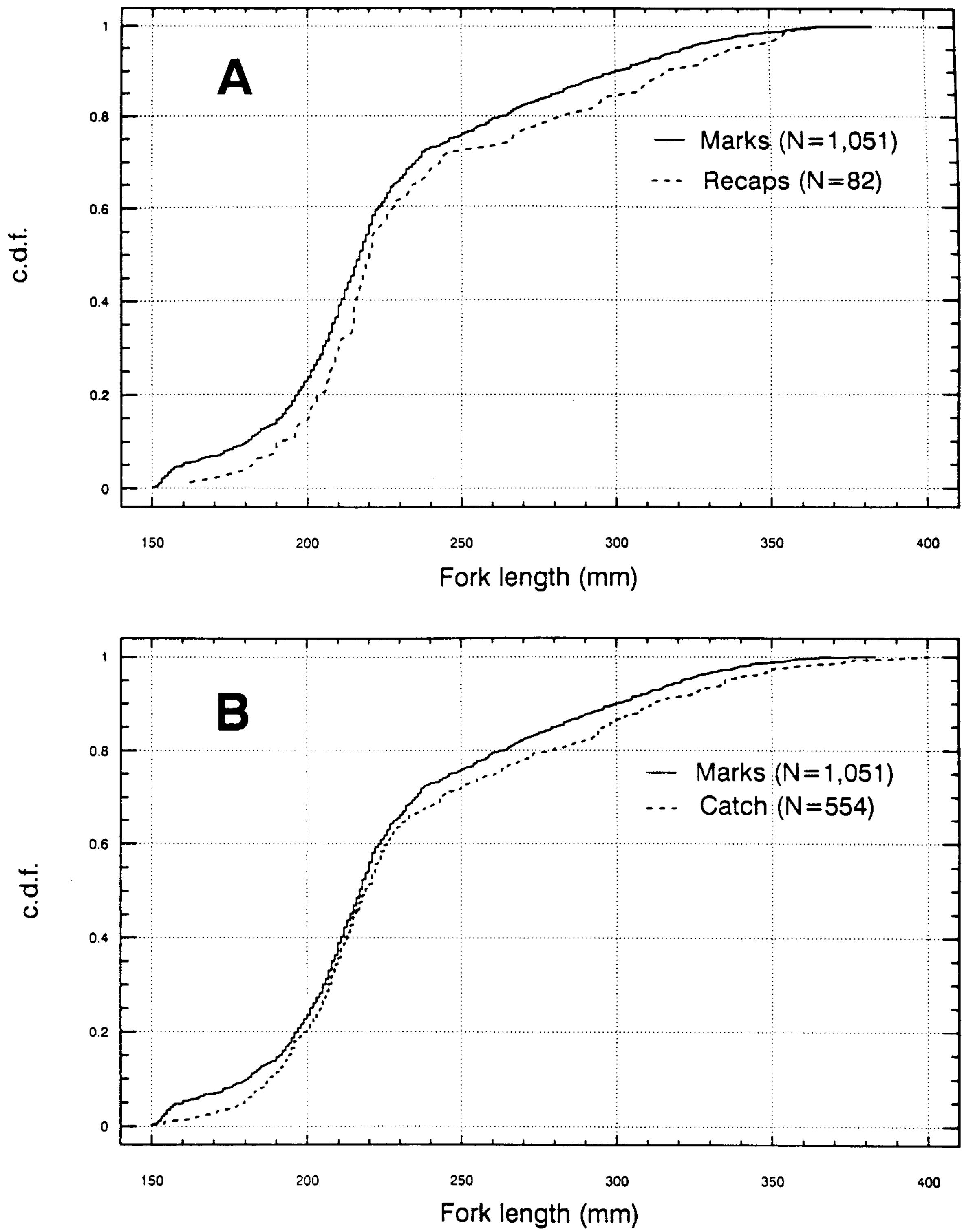

Figure 7. Cumulative distribution functions of lengths of Arctic grayling marked versus lengths of Arctic grayling recaptured (A) and versus lengths of Arctic grayling examined for marks (B) for a 50.0 km section of the Goodpaster River, 8 through 16 August, 1990.

Table 8. Summary of inter-section and inter-run[a] movements of Arctic grayling (≥ 150 mm FL) based on recaptures (R) in the lower 50.0 km of the Goodpaster River, 8 through 16 August, 1990.

Mark	Recapture: Section 3										Section 2									Section 1									RNM[b]	RM[c]	Total R	Total M	R/M Ratio
Run #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28					
1	4																												4	0	4	21	0.19
2		2																								1			2	1	3	20	0.15
3		1	5																										5	1	6	13	0.46
4				0																									0	0	0	6	0.00
5		1			0																								0	1	1	8	0.12
6						1				1																			1	1	2	14	0.14
7							0																				1		0	1	1	17	0.06
8								2																					2	0	2	16	0.12
9									1																				1	0	1	16	0.06
10										1																			1 (16)	0 (5)	1 (21)	18 (149)	0.05 (0.15)
11											1																		1	0	1	15	0.06
12												2																	2	0	2	32	0.06
13													1																1	0	1	43	0.02
14														1															1	0	1	42	0.02
15															5														5	0	5	47	0.11
16																2		1											2	1	3	52	0.06
17																	1												1	0	1	79	0.01
18																		1											1	0	1	71	0.01
19																		2	4						1				4 (18)	3 (4)	7 (22)	66 (447)	0.11 (0.05)
20																				5	1			1					5	2	7	64	0.11
21																			1		3								3	1	4	72	0.05
22																					1	5	1						5	2	7	74	0.09
23																						1	4						4	1	5	56	0.09
24																								1					1	0	1	46	0.02
25																									4	2			4	2	6	45	0.13
26																										4			4	0	4	57	0.07
27																										1	2		2	1	3	23	0.13
28																										1		1	1 (29)	1 (10)	2 (39)	18 (455)	0.11 (0.08)

[a] Locations are broken into river sections (see Methods) and run number. A run is approximately 1.8 km long, the distance covered by a 20 minute downstream pass of an electrofishing boat. Run 1 starts at river km 52.3 and run 28 ends at river km 1.7.

[b] RNM = Fish recaptured in same run as marked. Since marked fish were released at the end of a run, recaptures of these fish in the next run downstream were considered to be recaptured in the same location. An exception is fish marked in the last run of a section since they were released 1 km above the lower boundary of the run.

[c] RM = Fish recaptured either up or downstream of marking location.

significant movement of small fish among the three study areas was detected ($\chi^2 = 2.3$, $df = 1$, $0.1 < P < 0.5$). Large fish did not exhibit significant movement either ($\chi^2 = 1.7$, $df = 1$, $0.1 < P < 0.5$). Therefore, abundance of each size category was estimated with the modified Petersen estimator of Bailey. The abundance of small fish was 3,775 fish (SE = 616 fish, CV = 16%), while the abundance of large fish was 3,483 fish (SE = 463 fish, CV = 13%. The sum of the stratified abundance estimates for the lower 50 km of the Goodpaster River was 7,258 fish (SE = 770 fish, CV = 11%), while the unstratified abundance estimate was 7,113 fish (SE = 489 fish, CV = 7%; Table 9).

The second Kolmogorov-Smirnov test, comparison of length frequencies of the mark and catch samples, resulted in marginally ($DN = 0.07$, $P = 0.07$) different, but functionally similar CDF's (Figure 7B). The lack of substantial differences allowed computation of age and size compositions from the pooled mark and catch samples. Necessary adjustments to age composition (because of gear selectivity) resulted in changes that ranged from 0% to 1% (Table 10). Consistent with expectations based on year-class strengths in 1989, age 3 fish predominated (59% of the stock), followed by age 4 fish (10% of the stock). A considerable shortage of age 2 fish (8% of the stock) with respect to past findings (Appendix B2) project poor recruitment of the 1988 year-class.

Size composition, reported as RSD, was dominated by stock size fish (84% of the stock; Table 5). Quality and preferred sizes of fish made up the balance of the stock, with 14% and 2%, respectively. Adjustments needed to correct for size selectivity resulted in changes of 1% to 3% in RSD estimates.

DISCUSSION

Salcha River

Using a methodology that was similar to that used in 1989 resulted in a similar level of relative precision in 1990 (CV of abundance estimate was 11% in 1989 and 1990). However, the 1989 estimate of abundance was stratified by length to compensate for size selectivity of the electrofishing boat. We could have stratified the estimation procedure for 1990, but we would have gained little accuracy and lost some precision. For example, the mark-recapture data from the Goodpaster River were stratified, although adjustments to age and size compositions were minimal and the abundance estimates differed by only 2%. However, precision was lost by stratifying the Goodpaster River data; CV decreased by 4% by not stratifying. Simply looking at the probability of not rejecting the null hypothesis (i.e., no selectivity) does not guarantee that marginal differences in the CDF's will be meaningful. *A priori* criteria for detecting significant changes in capture probability should be developed during the operational planning phase. For example, a phrase like "a maximum difference of 20% in the CDF's, if significant would be cause for stratification" could be built into the battery of tests used to provide direction in our analysis of capture probability. This example sets a level of 20%, but we are not certain of the appropriate level at this time. Alternatively, a cost/benefit analysis of stratification could help

Table 9. Stratified and unstratified estimates of Arctic grayling (≥ 150 mm FL) capture probability and abundance in a 50.0 km section of the Goodpaster River, 8 through 16 August, 1990.

Length category	Mark n_1	Catch n_2	Recap m	ρ[a]	SE[ρ][b]	N[c]	SE[N][d]
150 to 215 mm	494	243	32	0.06	0.01	3,775	616
≥ 216 mm	557	311	50	0.09	<0.01	3,483	463
Total	1,051	554	82	---	---	7,258	770
Unstratified	1,051	554	82	0.08	<0.01	7,113	489

[a] ρ is the probability of capture determined from bootstrap methods.
[b] SE[ρ] is the standard error of ρ determined from bootstrap methods.
[c] N is the estimated abundance in a stratified length category or unstratified population, determined through bootstrap methods.
[d] SE[N] is the bootstrap standard error of N.

Table 10. Estimates of the sampled and adjusted age composition, and sampled mean fork length (mm) at age for Arctic grayling (≥ 150 mm FL) captured in the lower 50.0 km of the Goodpaster River, 8 through 10 August, 1990.

	Sampled:		Adjusted:		Fork Length	
Age	n[b]	p[c]	p[d]	SE[e]	Mean	SD[f]
1	46	0.05	0.05	<0.01	156	5
2	79	0.08	0.08	<0.01	182	11
3	562	0.58	0.59	0.01	214	15
4	94	0.10	0.10	<0.01	252	20
5	36	0.04	0.04	<0.01	278	23
6	55	0.06	0.05	<0.01	297	26
7	60	0.06	0.06	0.01	311	24
8	13	0.01	0.01	<0.01	321	28
9	8	0.01	0.01	<0.01	345	18
10	4	<0.01	<0.01	<0.01	365	57
Total	957	1.00	1.00		228	45

[a] Age composition is adjusted to compensate for length bias in the electrofishing sample.
[b] n = sample size.
[c] p = proportion of sampled grayling.
[d] p = adjusted proportion of grayling (≥ 150 mm) in stock.
[e] SE = standard error of the adjusted proportion.
[f] SD = standard deviation of the mean fork length.

researchers objectively decide if the extra accuracy was worth the inevitable loss in precision. For example, we realized a 2% increase in accuracy (assuming the mark-recapture data fit the estimation model) for the Goodpaster River estimate, but lost 4% in relative precision for a cost/benefit ratio of 2.0 (4% divided by 2%). More research should be done in this area of abundance estimation.

Relative recruitment in 1990, defined as the proportion of age 3 fish in the stock, was the highest since age composition estimates have been performed in this section of the Salcha River (since 1987). It appears that the 1987 year-class was strong in all of the runoff rivers assessed in 1990 (this includes all three rivers in this report and the Chena River). Regulatory actions taken in 1988 should allow this year-class to attain maturity without experiencing any directed fishing mortality, thereby increasing spawner abundance in the Salcha River. However the efficacy of special regulations on the Salcha River cannot be fully assessed until additional population data are collected. As a prime example, we have no age or size at maturity information specific to the Salcha River to assess the merits of the 305 mm minimum length limit. These parameters should be estimated in spring of 1991 or 1992. Additionally, abundance and age and size composition data should continue to be collected in the study section used in 1990.

Chatanika River

The 1990 estimate of abundance in the Chatanika River was the first since an estimate was performed in a 6.4 km section of the river in 1985. The experiment was successful for three reasons. First, the river section appears to be long enough (28.8 km) to allow for sufficient numbers of marked fish, given the efficiency of electrofishing. Second, movement of marked fish did occur, but the movements did not dominate the recapture data. This implies that population closure during the experiment was sufficient for using the modified estimator of Bernard. Thirdly, the experiment was performed within a two week time span, thereby preventing growth recruitment or mortality to occur. However, performing experiments of this kind during fall may confound efforts to reliably measure population size on an annual basis. The unusually high estimate of density of Arctic grayling (670 fish per kilometer) in the river section could be due to factors other than abundance of resident fish in the section. Water level was extremely high during the experiment, and water temperature was decreasing. Unmarked fish migrating downstream for overwintering or pushed downstream by high water level could have biased the estimate of abundance. If additional numbers of Arctic grayling migrated to the river section during the experiment, they must have done so equally among the three areas within the section because recapture rate did not vary by area. Downstream movement of fish was detected with recaptures of marked fish, although the rate of movement did not indicate any wholesale downstream migration of the stock. If the density of Arctic grayling in the Chatanika River is higher than the Salcha or Goodpaster Rivers, additional effort will be needed to mark the approximately 1,200 to 1,500 fish needed for precise estimation of abundance and movement.

As was found in the other rivers assessed in this report, a strong 1987 year-class was present in the study section. While no special regulations have been introduced for the Chatanika River fishery, assessment of age and size at maturity would be valuable to determine the proportion of spawners in the stock. For example, assuming a value of 270 mm FL for the 50% value of size at maturity, very few of the fish in the river section would qualify as spawners (~1,900 fish) in spring of 1990 or 1991. These parameters should be estimated in spring of 1991 or 1992. Additionally, abundance and age and size composition data should continue to be collected in the study section used in 1990.

Goodpaster River

Estimated density of Arctic grayling in 1990 (145 fish per kilometer, SE = 15) was similar to density estimated in 1989 (161 fish per kilometer, SE = 15). Densities estimated prior to 1989 (1987 and 1988) are also similar to the density estimated for 1990, but are germane to subsections of the river section and were estimated with different methods. This would lead one to believe that abundance has not changed appreciably in the preceding four years. Looking at age composition, age 3 fish predominated in the stock in 1990. This was foretold by a strong age 2 component in the 1989 estimate of age composition (Clark and Ridder 1990). However, age 1 and age 2 fish are likely only partially recruited to the defined stock in our assessment program (≥ 150 mm FL). When partially recruited age-classes are discounted from the density estimates at hand, the 1990 density estimate appears larger (124 fish per kilometer) than the 1989 density estimate (85 fish per kilometer). Similarly the 1987 and 1988 estimates of Arctic grayling density become 111 and 128 fish per kilometer, respectively.

Although results of length frequency analysis and movement did not necessitate stratification and the use of estimators to adjust for movement, both were investigated. Stratification occurred at a small fork length (215 mm) when compared to other years (259 mm in 1989) and other rivers (254 mm for the Chatanika River in 1990, and 250 mm for the Salcha River in 1989). No gross movements of fish were indicated by statistical tests, but two small fish marked in the upstream study area were later recaptured in the downstream area. In addition, twice as many large fish were marked as small fish in the upstream study area, but no movement was detected for large fish. It is not known why this occurred, but may relate to differential behavior of large and small fish, or an inadequate number of small fish marked, or may be the result of injuries to the two small fish during marking. If the movements of these two fish imply similar movements of unmarked fish, then population closure in the midstream area of the study section was violated and neither the Bailey nor Bernard estimator would be accurate.

There were several noteworthy occurrences that may have affected stock assessment in the Goodpaster River this year. First, hydrologic conditions varied considerably over the two sampling events in 1990. A storm event in the headwaters caused a 0.5 m rise in water level during the marking event, and unseasonably warm and dry weather lead to low water level and high water temperatures (14 to 18.5°C) during the recapture event. Secondarily, and possibly stemming from the aforementioned occurrences, numbers of fish captured and examined for marks were low when compared to the number of fish initially marked. Catches may have dropped during the recapture event because of fish movement to deeper, cooler areas, and reduced fishing efficiency resulting from low water level and high temperatures.

ACKNOWLEDGEMENTS

The authors wish to thank Mark D. Ross, James Harrild, George Schisler, Nicholas Hughes, Saree Timmons, Malcolm McEwen, and Steve Bodine for their skills at field sampling and data collection. Thanks also go to Dave Bernard for exposing the statistical procedures applied in this report. George Schisler, Nicholas Hughes, and David Davenport are commended for their help in mounting, pressing, and reading of scale samples. John H. Clark and Margaret F. Merritt are to be commended for their supervisory and coordination roles that provided the structure necessary for a successful field season and reporting process. The editorial efforts of Pat Hansen and Allen Bingham are also appreciated. Lastly, thanks goes to Sara J. Case for editing and final publication of the report text, tables, and figures. This project and report were made possible by partial funding provided by the U. S. Fish and Wildlife Service through the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-6, Job Number R-3-2(a).

LITERATURE CITED

Bailey, N. T. J. 1951. On estimating the size of mobile populations from capture-recapture data. Biometrika 38: 293-306.

_____. 1952. Improvements in the interpretation of recapture data. Journal of Animal Ecology 21: 120-127.

Baker, T. T. 1988. Creel censuses in interior Alaska in 1987. Alaska Department of Fish and Game, Fishery Data Series No. 64, Juneau, Alaska. 138 pp.

Bendock, T. 1974. Fisheries investigations on the Salcha and Tanana drainages - preliminary findings. First Interim Report of the Sport Fish Technical Evaluation Study. Alaska Department of Fish and Game. Special Report No. 6. 19 pp.

Clark, R. A. 1988. Stock assessment of Arctic grayling in the Salcha and Chatanika rivers. Alaska Department of Fish and Game, Fishery Data Series No. 74, Juneau, Alaska. 36 pp.

______. 1990. Stock status of Chena River Arctic grayling. Alaska Department of Fish and Game, Fishery Data Series No. 90-4, Anchorage, Alaska. 52 pp.

Clark, R. A. and W. P. Ridder. 1987. Abundance and length composition of selected grayling stocks in the Tanana drainage during 1986. Alaska Department of Fish and Game, Fishery Data Series No. 26, Juneau, Alaska. 55 pp.

______. 1988. Stock assessment of Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game, Fishery Data Series No. 54, Juneau, Alaska. 79 pp.

______. 1990. Stock assessment of Arctic grayling in the Salcha, Chatanika, and Goodpaster rivers. Alaska Department of Fish and Game, Fishery Data Series No. 90-7, Anchorage, Alaska. 84 pp.

Efron, B. 1982. The jackknife, the bootstrap, and other resampling plans. Society for Industrial and Applied Mathematics, Monograph 38, CBMS-NSF, Philadelphia, Pennsylvania.

Evenson, M. J. 1988. Movement, abundance, and length composition of Tanana River burbot stocks during 1987. Alaska Department of Fish and Game, Fishery Data Series No. 56, Juneau, Alaska. 42 pp.

Gabelhouse, D. W. 1984. A length-categorization system to assess fish stocks. North American Journal of Fisheries Management 4:273-285.

Hallberg, J. E. 1982. Distribution, abundance, and natural history of the Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1981-1982, Project F-9-14, 23(R-I). 35 pp.

Holmes, R. A. 1983. Distribution, abundance, and natural history of the Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1982-1983, Project F-9-15, 24(R-I). 35 pp.

_____. 1984. Population structure and dynamics of Arctic grayling, with emphasis on heavily fished stocks. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1983-1984, Project F-9-16, 25(R-I). 38 pp.

_____. 1985. Population structure and dynamics of Arctic grayling, with emphasis on heavily fished stocks. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1984-1985, Project F-9-17, 26(R-I). 38 pp.

Holmes, R. A., W. P. Ridder, and R. A. Clark. 1986. Population structure and dynamics of the Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1985-1986, Project F-10-1, 27(G-8-1). 68 pp.

Hop, H. 1985. Stock identification and homing of Arctic grayling *Thymallus arcticus* (Pallas) in interior Alaska. Master's thesis. University of Alaska, Fairbanks. 220 pp.

Kramer, M. J. 1975. Inventory and cataloging of interior Alaska waters - Fairbanks district. Alaska Department of Fish and Game. Federal Aid in Sport Fish Restoration, Annual Report of Progress, 1974-1975, Project F-9-7, 16(G-I-G): 145-181.

Marquardt, D. W. 1963. An algorithm for least-squares estimation of nonlinear parameters. Journal for the Society of Industrial and Applied Mathematics 11: 431-441.

Mills, M. J. 1979. Alaska statewide sport fish harvest studies (1977). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1978-1979, Project F-9-11, 20(SW-I-A). 122 pp.

______. 1980. Alaska statewide sport fish harvest studies (1978). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1979-1980, Project F-9-12, 21(SW-I-A). 65 pp.

______. 1981a. Alaska statewide sport fish harvest studies (1979). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1980-1981, Project F-9-13, 22(SW-I-A). 77 pp.

______. 1981b. Alaska statewide sport fish harvest studies (1980). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1980-1981, Project F-9-13, 22(SW-I-A). 107 pp.

______. 1982. Alaska statewide sport fish harvest studies (1981). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1981-1982, Project F-9-14, 23(SW-I-A). 115 pp.

______. 1983. Alaska statewide sport fish harvest studies (1982). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1982-1983, Project F-9-15, 24(SW-I-A). 118 pp.

______. 1984. Alaska statewide sport fish harvest studies (1983). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1983-1984, Project F-9-16, 25(SW-I-A). 123 pp.

______. 1985. Alaska statewide sport fish harvest studies (1984). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1984-1985, Project F-9-17, 26(SW-I-A). 137 pp.

______. 1986. Alaska statewide sport fish harvest studies (1985). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1985-1986, Project F-10-1, 27(RT-2). 137 pp.

______. 1987. Alaska statewide sport fisheries harvest report (1986). Alaska Department of Fish and Game, Fishery Data Series No. 2, Juneau, Alaska. 140 pp.

_____. 1988. Alaska statewide sport fisheries harvest report (1987). Alaska Department of Fish and Game, Fishery Data Series No. 52, Juneau, Alaska. 142 pp.

_____. 1989. Alaska statewide sport fisheries harvest report (1988). Alaska Department of Fish and Game, Fishery Data Series No. 122, Juneau, Alaska. 142 pp.

. 1990. Harvest and participation in Alaska sport fisheries during 1989. Alaska Department of Fish and Game, Fishery Data Series No. 90-44, Anchorage, Alaska. 152 pp.

Nagata, T. 1963. Investigations of the Tanana River grayling fisheries: migration study. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1962-1963, Project F-5-R-4, 4(14-B): 483-505.

Peckham, R. D. 1976. Evaluation of Interior Alaska waters and sport fish with emphasis on managed water, Delta District. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1975-1976. Project F-9-8, 17(G-III-I): 31-50.

_____. 1977. Evaluation of interior Alaska waters and sport fish with emphasis on managed waters, Delta District. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1976-1977. Project F-9-9, 18(G-III-I): 88-105.

_____. 1978. Evaluation of interior Alaska waters and sport fish with emphasis on managed waters, Delta District. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1977-1978. Project F-9-10, 19(G-III-I): 63-82.

_____. 1979. Evaluation of interior Alaska waters and sport fish with emphasis on managed waters, Delta District. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1978-1979. Project F-9-11, 20 (G-III-I): 87-114.

_____. 1980. Evaluation of interior Alaska waters and sport fish with emphasis on managed waters, Delta District. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1979-1980. Project F-9-12, 21(G-III-I): 1-47.

_____. 1981. Evaluation of interior Alaska waters and sport fish with emphasis on managed waters, Delta District. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1980-1981. Project F-9-13, 22(G-III-I): 1-25.

______. 1983. Evaluation of interior Alaska waters and sport fish with emphasis on managed waters, Delta District. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1982-1983. Project F-9-15, 24(G-III-I): 1-38.

Reed, R. J. 1961. Investigations of the Tanana River grayling fisheries: creel census - Chatanika and Delta Clearwater Rivers. Alaska Department of Fish and Game. Federal Aid in Sport Fish Restoration, Annual Report of Progress, 1960-1961, Project F-5-R-2, Job 3-C.

Reynolds, J. B. 1983. p. 147-163. *In* L. A. Nielsen and D. L. [ed.] Fisheries techniques, American Fisheries Society, Bethesda, Maryland USA.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada No. 191. 382 pp.

Ridder, W. P. 1983. A study of a typical spring-fed stream of interior Alaska. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1982-1983, Project F-9-15, 24(G-III). 54 pp.

______. 1985. Life history and population dynamics of exploited grayling stocks - Delta and Richardson Clearwater Rivers. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Report of Progress, 1984-1985. Project F-9-17, 26(G-III-G):1-58.

______. 1989. Age, length, sex, and abundance of Arctic grayling in the Goodpaster River, 1956 through 1988. Alaska Department of Fish and Game, Fishery Data Series No. 94, Juneau, Alaska. 49 pp.

Roguski, E. A. 1967. Investigations of the Tanana River and Tangle Lakes grayling fisheries: migratory and population study. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1966-1967, Project F-5-R-8, 8(16-B): 247-255.

Roguski, E. A. and P. C. Winslow. 1969. Investigations of the Tanana River and Tangle Lakes grayling fisheries: migratory and population study. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1968-1969, Project F-9-1, 10(16-B): 333-351.

Roguski, E. A. and S. L. Tack. 1970. Investigations of the Tanana River and Tangle Lakes grayling fisheries: migratory and population study. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1969-1970, Project F-9-2, 11(16B): 303-319.

Seber, G. A. F. 1982. The estimation of animal abundance and related parameters. Charles Griffin and Co., Ltd. London, U.K. 654 pp.

Snedecor, G. W. and W. G. Cochran. 1980. Statistical methods, seventh edition. The Iowa State University Press, Ames, Iowa. 507 pp.

Tack, S. L. 1971. Distribution, abundance, and natural history of the Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1970-1971, Project F-9-3, 12(R-1). 35 pp.

_____. 1973. Distribution, abundance, and natural history of the Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1972-1973, Project F-9-5, 14(R-1). 34 pp.

_____. 1974. Distribution, abundance, and natural history of the Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1973-1974. Project F-9-6, 15(R-I). 52 pp.

_____. 1975. Distribution, abundance, and natural history of the Arctic grayling in the Tanana River drainage . Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1974-1975. Project F-9-7, 16(R-I). 35 pp.

_____. 1980. Distribution, abundance, and natural history of the Arctic grayling in the Tanana River drainage . Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1971-1980. Project F-9-12, 21(R-I). 32 pp.

Townsend, A. H. 1987. Placer mining in the upper Chatanika River system 1980-1986. Alaska Department of Fish and Game, Division of Habitat, Technical Report No. 87-2, Juneau, Alaska. 29 pp.

USGS. 1976-1989. Water Resources Data - Alaska. U.S. Geological Survey Water-Data Reports.

Van Hulle, F. D. 1968. Investigations of fish populations in the Chena River. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1967-1968, Project F-5-R-9, 9:287-304.

Van Whye, G. 1964. Investigations of the Tanana River grayling fisheries: migration study. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Job Completion Report, 1963. Project F-5-R-5, 5(14-B). 16 pp.

Warner, G. 1957. Movements and migrations of grayling in Interior Alaska. U.S. Fish and Wildlife Service, Federal Aid in Fish Restoration, Quarterly Progress Report. Project F-1-R-6, Work Plan C, Job No. 3, 6(4). 5 pp.

______. 1958. Movements and migrations of grayling in Interior Alaska. U.S. Fish and Wildlife Service, Federal Aid in Fish Restoration, Quarterly Progress Report. Project F-1-R-7, Work Plan C, Job No. 3, 7(3). 15 pp.

______. 1959a. Tagging and migration of grayling in Interior Alaska. U.S. Fish and Wildlife Service, Federal Aid in Fish Restoration, Quarterly Progress Report. Project F-1-R-8, Work Plan C, Job No. 3, 8(2). 10 pp.

______. 1959b. Catch distribution, age and size composition sport fish in Fairbanks area. U.S. Fish and Wildlife Service, Federal Aid in Fish Restoration, Quarterly Progress Report. Project F-1-R-8, Work Plan A, Job 3c, 8(3). 7 pp.

Wojcik, F. J. 1954. Game fish investigations of Alaska. U.S. Fish and Wildlife Service and Alaska Game Commission. Federal Aid in Fish Restoration, Work Plan No. 5, Job No. 1.

______. 1955. Life history and management of the grayling in interior Alaska. M.S. Thesis. University of Alaska - Fairbanks. 54 pp.

APPENDIX A

Historic Data Summaries - Salcha and Chatanika Rivers

Appendix A1. Summary of recreational effort and catch rate estimates for Arctic grayling harvested from the Salcha and Chatanika rivers, 1953-1958, 1960, 1963-1964, 1974, 1987[a].

	Salcha River			Chatanika River		
Year	Interviews	Angler-hours	GR/hr[b]	Interviews	Angler-hours	GR/hr
1953	102	344	0.48	460	955	0.49
1954	132	646	0.84	243	529	0.78
1955[c]	174	728	1.09	69	294	0.13
1956[c]	391	1,659	0.83	66	223	0.27
1957[c]	86	321	0.78	62	177	0.18
1958[c]	108	423	1.01	68	151	0.76
1960	ND	2,600	1.22	---	---	---
1963	275	---	0.67[d]	---	---	---
1964	409	1,816	0.64	---	---	---
1968	2,013[e]	7,035[e]	1.00	---	---	---
1974	827	11,284[e]	0.42	408	27,250[e]	1.02
1987	152	---	0.66	30	---	0.02

[a] Statistics taken from Warner (1959b) for 1953-1958, Reed (1961) for 1960, Roguski and Winslow (1969) for 1963-1968, Kramer (1975) for 1974, and Baker (1988) for 1987.

[b] GR/hr is the number of Arctic grayling harvested per angler-hour.

[c] From 1955 through 1958 there was a 305 mm (12 inch) minimum length limit for Arctic grayling on the Chatanika River (Warner 1959b).

[d] This catch rate includes salmon (Roguski and Winslow 1969).

[e] Data expanded from sample time/area to the entire fishery.

Appendix A2. Summary of population abundance estimates of Arctic grayling in the Salcha River, 1972, 1974, 1985, 1988-1990[a].

Dates	Area	Marks	Recaps	Estimate[b]	Confidence[c]
8/2-8/4/72	Redmond Creek	ND[d]	5	503/km	Low
7/10-7/22/74	Redmond Creek to TAPS[e]	ND	ND	765/km	490-5,032/km
7/10-7/22/74	TAPS to 8 km upstream	ND	ND	991/km	690-2,595/km
7/10-7/22/74	TAPS to 8 km downstream	ND	ND	551/km	397-1,174/km
8/5-8/9/85	Flat Creek	205	6	497/km	128-1,064/km
5/24-6/8/88	TAPS to 16 km upstream	208	28	138/km	SE = 34/km
6/12-6/16/89	Richardson Hwy. bridge to 36.8 km upstream	616	55	188/km	SE = 21/km
6/26-6/27/90	Richardson Hwy. bridge to 36.8 km upstream	495	40	157/km	SE = 18/km

[a] Data sources are:
1972 - Tack (1973);
1974 - Bendock (1974) and Kramer (1975);
1985 - Holmes, et al. (1986);
1988 - Clark (1988);
1989 - Clark and Ridder (1990); and,
1990 - this report.

[b] All estimates are calculated with the modified Schnabel formula (Ricker 1975) except the 1988 through 1990 estimates. The 1988 through 1990 estimates are calculated with a modified Petersen estimate of Evenson (1988).

[c] Confidence is a crude measure of precision (e.g. Low) or the 95% confidence interval based on a Poisson distribution of recaptures (Ricker 1975). Estimates for 1988, 1989, and 1990 were from bootstrap methods (Efron 1982); a standard error (SE) is reported for these estimates.

[d] ND = data not furnished in original citation.

[e] TAPS = Trans-Alaska Pipeline System.

Appendix A3. Summary of age composition estimates and standard error of Arctic grayling ($\geq$ 150 mm FL) collected from the Salcha River, 1985-1990[a].

	1985[b]			1986[c]			1987[d]			1988[e]			1989[f]			1990[g]		
Age Class	n	p	SE	n	p	SE	n	p	SE	n	p	SE	n	p	SE	n	p	SE
2	1	0.01	0.01	0	0.00	---	2	<0.01	<0.01	17	0.03	0.01	17	0.03	0.01	45	0.22	0.03
3	13	0.06	0.02	19	0.12	0.03	35	0.07	0.01	116	0.20	0.02	155	0.35	0.03	76	0.37	0.03
4	3	0.01	0.01	25	0.16	0.03	205	0.40	0.02	83	0.14	0.01	143	0.26	0.02	38	0.19	0.03
5	29	0.13	0.02	14	0.09	0.02	120	0.23	0.02	175	0.30	0.02	75	0.13	0.01	18	0.09	0.02
6	69	0.32	0.03	37	0.24	0.03	80	0.15	0.02	58	0.10	0.01	74	0.11	0.02	13	0.06	0.02
7	58	0.27	0.03	26	0.17	0.03	56	0.11	0.01	54	0.09	0.01	24	0.04	0.01	7	0.03	0.01
8	25	0.12	0.02	22	0.14	0.03	15	0.03	0.01	51	0.09	0.01	30	0.05	0.01	5	0.02	0.01
9	18	0.08	0.02	8	0.05	0.02	4	0.01	<0.01	22	0.04	0.01	18	0.03	0.01	1	<0.01	<0.01
10	2	0.01	0.01	3	0.02	0.01	2	<0.01	<0.01	4	0.01	<0.01	3	<0.01	<0.01	0	0.00	---
11	0	0.00	---	1	0.01	0.01	0	0.00	---	1	<0.01	<0.01	0	0.00	---	0	0.00	---
Totals	218	1.00		154	1.00		519	1.00		581	1.00		539	1.00		203	1.00	

[a] Source documents are: 1985 - Holmes, et al. (1986); 1986 - Clark and Ridder (1987); 1987 - Clark and Ridder (1988); 1988 - Clark (1988); 1989 - Clark and Ridder (1990); and 1990 - this report.

[b] Sampling was conducted with an AC electrofishing boat and hook-and-line gear from river km 64.0 to river km 57.6 (5-9 August 1985).

[c] Sampling was conducted with a DC electrofishing boat and hook-and-line gear from river km 112.0 to river km 4.8 (11-15 August 1986).

[d] Sampling was conducted with a DC electrofishing boat from river km 38.6 to river km 4.8 (1-9 June 1987).

[e] Sampling was conducted with a DC electrofishing boat from river km 38.6 to river km 16.0 (24 May through 9 June 1988).

[f] Sampling was conducted with a DC electrofishing boat from river km 0 to 38.6 (12 through 16 June 1989). Age composition and standard error are adjusted for differential probability of capture by size of fish.

[g] Sampling was conducted with a DC electrofishing boat from river km 0 to 38.6 (19 through 27 June 1990).

Appendix A4. Summary of Relative Stock Density indices of Arctic grayling captured in the Salcha River, 1972, 1974, 1985-1990[a].

	RSD Category[b]				
	Stock	Quality	Preferred	Memorable	Trophy
1972 - Number sampled	ND[c]	ND	ND	ND	ND
RSD	0.53	0.46	<0.01	0	0
SE	ND	ND	ND	---	---
1974 - Number sampled	153	14	2	0	0
RSD	0.91	0.08	0.01	---	---
SE	0.02	0.02	0.01	---	---
1985 - Number sampled	17	155	57	0	0
RSD	0.07	0.68	0.25	---	---
SE	0.02	0.03	0.03	---	---
1986 - Number sampled	47	71	56	0	0
RSD	0.27	0.41	0.32	---	---
SE	0.03	0.04	0.04	---	---
1987 - Number sampled	275	171	71	1	0
RSD	0.53	0.33	0.14	<0.01	---
SE	0.02	0.02	0.02	<0.01	---
1988 - Number sampled	280	217	110	1	0
RSD	0.46	0.36	0.18	<0.01	---
SE	0.02	0.02	0.02	<0.01	---
1989 - Number sampled	755	342	124	2	0
RSD[d]	0.71	0.22	0.08	<0.01	---
SE	0.04	0.03	0.01	<0.01	---
1990 - Number sampled	365	95	40	0	0
RSD	0.73	0.19	0.08	---	---
SE	0.02	0.02	0.01	---	---

[a] Data sources:
1972 - Tack (1973); 1974 - Bendock (1974) and Kramer (1975); 1985 - Holmes et al. (1986); 1986 - Clark and Ridder (1987); 1987 - Clark and Ridder (1988); 1988 - Clark (1988); 1989 - Clark and Ridder (1990); and, 1990 - this report.

[b] Minimum lengths for RSD categories are (Gabelhouse 1984):
Stock - 150 mm FL; Quality - 270 mm FL; Preferred - 340 mm FL; Memorable - 450 mm FL; and, Trophy - 560 mm FL.

[c] ND = data not furnished in original citation.

[d] RSD does not correspond to sample size because of adjustments made for differential capture probability by size of fish.

Appendix A5. Summary of mean length at age data collected from Arctic grayling in the Salcha River, 1952, 1974, 1981, 1985-1990[a].

	1952			1974			1981			1985			1986			1987			1988			1989			1990		
Age Class	n[b]	FL[c]	SD[d]	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
1	ND[e]	103	---	6	111	---	20	126	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	123	---
2	ND	145	---	88	155	---	25	162	---	1	156	---	---	---	---	2	138	8	17	174	16	17	176	39	96	182	19
3	ND	185	---	61	196	---	11	197	---	13	223	15	19	218	16	35	203	36	116	200	16	155	214	24	220	213	22
4	ND	223	---	26	231	---	9	224	---	3	262	18	25	263	25	205	241	20	83	241	20	143	252	28	157	252	25
5	ND	261	---	16	278	---	7	254	---	29	292	10	14	291	26	120	275	33	175	280	24	75	273	30	75	283	32
6	ND	289	---	3	345	---	5	272	---	69	313	20	37	316	24	80	311	36	58	302	30	74	302	37	49	317	33
7	ND	318	---	---	---	---	8	302	---	58	332	16	26	328	40	56	339	30	54	332	32	24	315	38	38	346	31
8	---	---	---	---	---	---	5	335	---	25	346	15	22	360	30	15	356	36	51	348	24	30	341	44	19	370	33
9	---	---	---	---	---	---	1	353	---	18	378	24	8	372	18	4	371	30	22	373	30	18	368	21	6	396	36
10	---	---	---	---	---	---	---	---	---	2	403	90	3	405	16	2	444	20	4	394	19	3	407	40	0	---	---
11	---	---	---	---	---	---	---	---	---	---	---	---	1	364	---	---	---	---	1	463	---	0	---	---	0	---	---
Totals	32			200			91			219			155			519			581			539			661		

[a] Data sources: 1952 - Warner (1959b); 1974 - Bendock (1974) and Kramer (1975); 1981 - Hallberg (1982); 1985 - Holmes, et al. (1986); 1986 - Clark and Ridder (1987); 1987 - Clark and Ridder (1988); 1988 - Clark (1988); 1989 - Clark and Ridder (1990); and, 1990 - this report.

[b] n is the total number of fish aged.

[c] FL is the population mean fork length (mm) at age.

[d] SD is the population standard deviation of FL.

[e] ND = data not furnished in original citation.

Appendix A6. Summary of population abundance estimates of Arctic grayling in the Chatanika River, 1972, 1981, 1984-1985[a].

Dates	Area	Marks	Recaps	Estimate[b]	Confidence[c]
8/10-8/17/72	Elliot Highway Bridge	103	4	305/km	Low
8/24-8/26/81	Elliot Highway Bridge	ND[d]	64	169/km	132-197/km
8/15-8/18/84	Elliot Highway Bridge	ND	32	242/km	172-352/km
8/20-8/23/85	Elliot Highway Bridge	132	20	117/km	82-176/km
8/27-9/7/90	28.8 km section from 7.5 km above to Elliot Highway bridge downstream	857	36	670/km	SE = 111/km

[a] Data sources are:
1972 - Tack (1973);
1982 - Holmes (1983);
1984 - Holmes (1985);
1985 - Holmes, et al. (1986); and,
1990 - this report.

[b] All estimates except 1990 are calculated with the modified Schnabel formula (Ricker 1975). The 1990 estimate is calculated with the modified Petersen estimate of Evenson (1988) and the modified Petersen estimate of Bailey (1951,1952).

[c] Confidence is a crude measure of precision (e.g. Low), the 95% confidence interval based on a Poisson distribution of recaptures (Ricker 1975), or the standard error.

[d] ND = data not furnished in original citation.

Appendix A7. Summary of age composition estimates and standard error of Arctic grayling (≥ 150 mm FL) collected from the Chatanika River, 1984-1990[a].

	1984[b]			1985[c]			1986[d]			1987[e]			1988[f]			1989[g]			1990[h]		
Age Class	n	p	SE	n	p	SE	n	p	SE	n	p	SE	n	p	SE	n	p	SE	n	p	SE
2	2	0.04	0.03	131	0.55	0.03	0	0.00	---	11	0.02	0.01	22	0.04	0.01	24	0.09	0.03	126	0.20	0.02
3	8	0.14	0.05	5	0.02	0.01	119	0.31	0.02	50	0.09	0.01	44	0.09	0.01	47	0.18	0.04	347	0.55	0.02
4	22	0.39	0.07	31	0.13	0.02	16	0.04	0.01	295	0.55	0.02	63	0.12	0.01	31	0.12	0.03	80	0.11	0.01
5	17	0.30	0.06	59	0.25	0.03	71	0.18	0.02	32	0.06	0.01	216	0.42	0.02	30	0.08	0.02	45	0.04	0.01
6	5	0.09	0.04	12	0.05	0.01	119	0.31	0.02	47	0.09	0.01	48	0.09	0.01	88	0.23	0.04	51	0.04	0.01
7	1	0.02	0.02	0	0.00	---	47	0.12	0.02	106	0.19	0.02	55	0.11	0.01	54	0.14	0.03	57	0.04	0.01
8	1	0.02	0.02	0	0.00	---	12	0.03	0.01	8	0.01	0.01	61	0.12	0.01	47	0.12	0.03	17	0.01	<0.01
9	0	0.00	---	0	0.00	---	2	0.01	0.00	3	0.01	<0.01	5	0.01	<0.01	15	0.04	0.01	11	0.01	<0.01
10	0	0.00	---	0	0.00	---	0	0.00	---	1	<0.01	<0.01	1	<0.01	<0.01	2	0.01	<0.01	2	<0.01	<0.01
Totals	56	1.00		238	1.00		386	1.00		553	1.00		515	1.00		338	1.00		736	1.00	

[a] Source documents are: 1984 - Holmes (1985); 1985 - Holmes, et al. (1986); 1986 - Clark and Ridder (1987); 1987 - Clark and Ridder (1988); 1988 - Clark (1988); 1989 - Clark and Ridder (1990); and, 1990 - this report.

[b] Sampling was conducted with an AC electrofishing boat near the Elliot Highway bridge (15-18 August 1984).

[c] Sampling was conducted with an AC electrofishing boat near the Elliot Highway bridge (20-23 August 1985).

[d] Sampling was conducted with a DC electrofishing boat near the Elliot Highway bridge (4-28 August 1986).

[e] Sampling was conducted with a DC electrofishing boat near the Elliot Highway bridge (10-13 August 1987).

[f] Sampling was conducted with a DC electrofishing boat near the Elliot Highway bridge (15-26 August and 7-20 September 1988).

[g] Sampling was conducted with a DC electrofishing boat downstream of the Elliot Highway bridge (12 through 28 September 1989). Age composition and standard error are adjusted for differential probability of capture by size of fish.

[h] Sampling was conducted with a DC electrofishing boat in a 28.8 km section, beginning 7.5 km upstream of the Elliot Highway bridge and ending 21.3 km downstream of the bridge (27 August through 7 September 1990). Age composition and standard error are adjusted for differential probability of capture by size of fish.

Appendix A8. Summary of Relative Stock Density indices of Arctic grayling captured in the Chatanika River, 1952-1954, 1972, 1982, 1984-1990[a].

		RSD Category[b]				
		Stock	Quality	Preferred	Memorable	Trophy
1952	Number sampled	95	1	0	0	0
	RSD	0.99	0.01	---	---	---
	SE	0.01	0.01	---	---	---
1953	Number sampled	98	8	0	0	0
	RSD	0.92	0.08	---	---	---
	SE	0.03	0.03	---	---	---
1954	Number sampled	42	1	0	0	0
	RSD	0.98	0.02	---	---	---
	SE	0.02	0.02	---	---	---
1972	Number sampled	121	0	0	0	0
	RSD	1.00	---	---	---	---
	SE	---	---	---	---	---
1982	Number sampled	53	3	0	0	0
	RSD	0.95	0.05	---	---	---
	SE	0.03	0.03	---	---	---
1984	Number sampled	206	9	1	0	0
	RSD	0.95	0.04	0.01	---	---
	SE	0.01	0.01	0.01	---	---
1985	Number sampled	146	11	0	0	0
	RSD	0.93	0.07	---	---	---
	SE	0.02	0.02	---	---	---
1986	Number sampled	279	121	4	0	0
	RSD	0.69	0.30	0.01	---	---
	SE	0.02	0.02	0.01	---	---
1987	Number sampled	420	126	7	0	0
	RSD	0.76	0.23	0.01	---	---
	SE	0.02	0.02	0.01	---	---
1988	Number sampled	361	221	13	0	0
	RSD	0.61	0.37	0.02	---	---
	SE	0.02	0.02	0.01	---	---

-continued-

Appendix A8. (Page 2 of 2).

	RSD Category[b]				
	Stock	Quality	Preferred	Memorable	Trophy
1989 - Number sampled	150	221	4	0	0
RSD[c]	0.49	0.49	0.02	---	---
SE	0.06	0.06	0.01	---	---
1990 - Number sampled	1,201	309	19	0	0
RSD[c]	0.90	0.09	0.01	---	---
SE	0.02	0.02	<0.01	---	---

[a] Data sources:
1952-1958 - Warner (1959b);
1972 - Tack (1973);
1982 - Holmes (1983);
1984 - Holmes (1985);
1985 - Holmes, et al. (1986);
1986 - Clark and Ridder (1987);
1987 - Clark and Ridder (1988);
1988 - Clark (1988);
1989 - Clark and Ridder (1990); and,
1990 - this report.

[b] Minimum lengths for RSD categories are (Gabelhouse 1984):
Stock - 150 mm FL;
Quality - 270 mm FL;
Preferred - 340 mm FL;
Memorable - 450 mm FL; and,
Trophy - 560 mm FL.

[c] RSD does not correspond to sample size because of adjustments made for differential capture probability by size of fish.

Appendix A9. Summary of mean length at age data collected from Arctic grayling in the Chatanika River, 1952-1953, 1981-1982, 1984-1990[a].

	1952			1953			1981			1982			1984			1985		
Age Class	n[b]	FL[c]	SD[d]	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
1	ND[e]	94	---	19	96	---	0	---	---	5	95	---	16	101	---	0	---	---
2	ND	133	---	77	144	---	4	169	---	29	135	---	3	149	---	131	147	15
3	ND	176	---	129	190	---	7	204	---	22	187	---	8	172	---	5	181	25
4	ND	212	---	28	207	---	10	233	---	23	216	---	22	196	---	31	212	22
5	ND	243	---	4	226	---	7	264	---	5	236	---	17	225	---	59	233	24
6	---	---	---	9	254	---	3	286	---	2	280	---	5	251	---	12	268	18
7	---	---	---	---	---	---	1	290	---	1	252	---	1	258	---	---	---	---
8	---	---	---	---	---	---	---	---	---	1	334	---	1	301	---	---	---	---
9	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
10	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Totals	149			266			32			88			73			238		

-continued-

Appendix A9. (Page 2 of 2).

	1986			1987			1988			1989			1990		
Age Class	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
1	---	---	---	---	---	---	---	---	---	4	125	16	19	125	10
2	---	---	---	11	157	15	22	170	13	30	159	27	143	167	14
3	119	195	21	50	200	24	44	205	16	47	203	38	351	195	17
4	16	231	36	295	228	18	63	238	21	31	234	42	80	242	18
5	71	248	16	32	265	22	216	259	22	30	267	56	45	269	15
6	119	267	20	47	273	21	48	278	24	88	286	36	52	282	19
7	47	292	28	106	288	30	55	298	22	54	305	46	61	297	22
8	12	304	21	8	319	18	61	312	25	47	313	49	17	324	23
9	2	283	35	3	296	55	5	328	8	15	334	86	11	329	12
10	---	---	---	1	325		1	352	---	2	337	147	2	337	34
Totals	386			553			515			349			781		

[a] Data sources: 1952-1953 - Warner (1959b); 1981 - Hallberg (1982); 1982 - Holmes (1983); 1984 - Holmes (1985); 1985 - Holmes et al. (1986); 1986 - Clark and Ridder (1987); 1987 - Clark and Ridder (1988); 1988 - Clark (1988); 1989 - Clark and Ridder (1990); and, 1990 - this report.

[b] n is the total number of fish aged.

[c] FL is the mean fork length (mm) at age.

[d] SD is the standard deviation of FL.

[e] ND = data not furnished in original citation.

Appendix A10. Parameter estimates and standard errors of the von Bertalanffy growth model[a] for Arctic grayling from the Salcha and Chatanika rivers, 1986-1988[b].

	Salcha River		Chatanika River	
Parameter	Estimate	Standard Error	Estimate	Standard Error
L_{∞}[c]	489	19	375	11
K[d]	0.16	0.02	0.19	0.02
t_o[e]	-0.42	0.16	-1.01	0.20
$Corr(L_{\infty},K)$[f]	-0.99	---	-0.98	---
$Corr(L_{\infty},t_o)$	-0.88	---	-0.89	---
$Corr(K,t_o)$	0.94	---	0.96	---
Sample size	1,198		1,469	

[a] The form of the von Bertalanffy growth model (Ricker 1975) is as follows: $l_t = L_{\infty}(1 - exp(-K(t - t_o)))$. The parameters of this model were estimated with data collected during 1986 through 1988. This model was fitted to the data by nonlinear regression utilizing the Marquardt compromise (Marquardt 1963). The range of ages used to model growth were age 1 through age 11 for the Salcha River, and age 1 through age 10 for the Chatanika River.

[b] Source citation is Clark (1988).

[c] L_{∞} is the length a fish would achieve if it continued to live and grow indefinitely (Ricker 1975).

[d] K is a constant that determines the rate of increase of growth increments (Ricker 1975).

[e] t_o represents the hypothetical age at which a fish would have zero length (Ricker 1975).

[f] $Corr(x,y)$ is the correlation of parameter estimates x and y.

APPENDIX B

Historic Data Summary - Goodpaster River

Appendix B1. Summary of population abundance estimates of Arctic grayling ($\geq$ 150 mm FL) in the Goodpaster River, 1972 - 1990[a].

						Fish/km[b]		
Year	Month	River km	M	C	R	N	95% CI[c]	Rel.Prec
1972	12-14 Jul	4.8 - 9.6	210	---	30	189	---	---
1973	1 Jun-30 Aug	0 - 53	2,328	1,734	122	480	411 - 590	19%
		53 - 98	561	680	16	322	223 - 732	79%
		98 - 184	415	410	19	81	57 - 164	66%
		0 - 184	---	---	---	241	209 - 287	16%
1974[d]	15-29 Jul	0 - 53	1,217	489	55	201	155 - 260	26%
		53 - 98	479	279	9	298	165 - 596	72%
		98 - 184	343	275	27	63	44 - 93	40%
		0 - 184	---	---	---	152	124 - 186	20%
1975	23-27 Jun	4.8 - 9.6	330	145	31	314	223 - 456	37%
		24 - 28.8	317	319	34	604	436 - 863	35%
		combined	647	464	65	475	374 - 603	24%
1976	21-24 Jun	4.8 - 9.6	155	99	9	323	178 - 646	72%
		24 - 28.8	202	165	18	368	238 - 597	49%
		combined	357	264	27	351	245 - 524	40%
1977	21-24 Jun	4.8 - 9.6	234	150	11	613	356-1,150	65%
		24 - 28.8	396	263	60	357	278 - 457	25%
		combined	630	413	71	377	300 - 474	23%
1978	20-23 Jun	4.8 - 9.6	248	167	19	434	284 - 694	47%
		24 - 28.8	373	212	32	502	359 - 726	37%
		combined	621	379	51	473	361 - 618	27%
1980	24-27 Jun	4.8 - 9.6	231	153	13	529	318 - 938	59%
		24 - 28.8	337	213	31	470	334 - 683	37%
		combined	568	366	44	483	362 - 658	31%
1982	29 Jun-2 Jul	4.8 - 9.6	79	107	9	178	98 - 356	72%
		24 - 28.8	214	155	39	174	128 - 242	33%
		combined	293	260	48	163	123 - 219	30%
1984	27-29 Jun	4.8 - 9.6	265	91	12	391	153 - 629	61%
		24 - 28.8	216	169	28	264	161 - 367	39%
		combined	481	260	40	352	249 - 455	29%

-continued-

						Fish/km		
Year	Month	River km	M	C	R	N	.95 CI	Rel.Prec
1985	25-27 Jun	4.8 - 9.6	189	213	7	459	238 - 966	79%
1985	6-13 Aug	4.8 - 9.6	307	455	42	400	296 - 554	32%
		24 - 28.8	303	424	45	328	245 - 450	31%
		combined	610	879	87	364	271 - 502	32%
1986	11-15 Aug	4.8 - 9.6	230	312	15	403	250 - 686	54%
		24 - 28.8	293	389	42	256	193 - 352	31%
		combined	523	701	57	305	234 - 397	27%
1987	4-10 Aug	4.8 - 9.6	138	191	14	188	115 - 324	56%
		24 - 28.8	158	213	24	133	91 - 203	42%
		combined	274	363	35	134	97 - 191	35%
1988	8-18 Aug	4.8 - 53	1,130	1,002	139	158	SE= 12/km	
1989	8-17 Aug	3 - 53	955	984	124	161	SE= 15/km 139 - 192	17%
1990	8-16 Aug	3 - 53	1,051	554	82	145	SE= 15/km 131 - 168	21%

[a] Data sources: 1972 - 1974, Tack (1973, 1974, 1975); 1975 - 1978, 1980, Peckham (1976, 1977, 1978, 1979, 1981); 1982, 1984, Ridder (1983, 1985); 1985, Holmes, et al. (1986); 1986 - 1987, Clark and Ridder (1987, 1988), Ridder (1989); 1989, Clark and Ridder (1990); and, 1990 - this report.

[b] Schnabel estimator in 1972, 1973, 1985 through 1987; modified Peterson (Bailey 1951, 1952) estimator in 1974 through 1984; modified Peterson (Evenson 1988) in 1988; bootstrapped modified Peterson (Bailey 1951, 1952) in 1989 and 1990.

[c] The confidence interval is based on a Poisson distribution of recaptures (Ricker 1975). Estimates for 1988 through 1990 were from bootstrap methods (Efron 1982) and a standard error (SE) is reported.

[d] Estimate was based on total marks in 1973 which were adjusted with a mortality rate of 0.46 (Tack 1975). Number of marks presented shown for 1973 do not include those applied during the final 1973 sampling event.

Appendix B2. Summary of age composition estimates and standard errors for Arctic grayling sampled in the lower 53 km of the Goodpaster River, summer, 1955 - 1990[a].

	1955 29 July - 15 Sept.			1956 summer			1957 11 June - 15 Aug.			1958 7 May - 25 July			1969		
Age Class	n[b]	p[c]	SE[d]	n	p	SE	n	p	SE	n	p	SE	n	p	SE
1	14	0.08	0.02	15	0.05	0.01	3	0.01	<0.01	111	0.10	0.01	0	---	---
2	49	0.27	0.03	109	0.37	0.03	40	0.10	0.02	532	0.48	0.02	9	0.13	0.04
3	40	0.22	0.03	115	0.39	0.03	178	0.44	0.03	106	0.10	0.01	13	0.19	0.05
4	53	0.29	0.03	30	0.10	0.02	122	0.30	0.02	225	0.20	0.01	12	0.17	0.05
5	14	0.08	0.02	19	0.06	0.01	30	0.07	0.01	100	0.09	0.01	11	0.16	0.04
6	6	0.03	0.01	5	0.02	0.01	19	0.05	0.01	16	0.01	<0.01	9	0.13	0.04
7	5	0.03	0.01	4	0.01	0.01	6	0.02	0.01	10	0.01	<0.01	4	0.06	0.03
8	0	---	---	0	---	---	5	0.01	0.01	4	<0.01	<0.01	7	0.10	0.04
9	0	---	---	0	---	---	1	<0.01	<0.01	0	---	---	4	0.06	0.03
10	0	---	---	0	---	---	0	---	---	0	---	---	1	0.01	0.01
11	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
12	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
Total	181	1.00		297	1.00		404	1.00		1104	1.00		70	1.00	

-continued-

Appendix B2. (Page 2 of 4).

	1973[e] 15 June - 15 Aug.			1975 23 June - 24 June			1976 21 June - 22 June			1977 21 June - 22 June			1978 21 June - 22 June		
Age Class	n	p	SE	n	p	SE	n	p	SE	n	p	SE	n	p	SE
1	0	---	---	3	0.03	0.02	1	0.01	0.01	8	0.07	0.02	2	0.02	0.01
2	3	0.03	0.02	3	0.03	0.02	13	0.11	0.03	1	0.01	0.01	23	0.22	0.04
3	65	0.65	0.05	52	0.52	0.05	13	0.11	0.03	76	0.66	0.04	13	0.13	0.03
4	27	0.27	0.05	7	0.07	0.03	44	0.37	0.04	6	0.05	0.02	58	0.56	0.05
5	2	0.02	0.01	29	0.29	0.05	25	0.21	0.04	13	0.11	0.03	8	0.08	0.03
6	3	0.03	0.02	5	0.05	0.02	22	0.18	0.03	12	0.10	0.03	0	---	---
7	0	---	---	1	0.01	0.01	1	0.01	0.01	0	---	---	0	---	---
8	0	---	---	0	---	---	1	0.01	0.01	0	---	---	0	---	---
9	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
10	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
11	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
12	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
Total	100	1.00		100	1.00		120	1.00		116	1.00		104	1.00	

-continued-

Appendix B2. (Page 3 of 4).

	1980			1982			1984			1985[e]			1985[e]		
	24 June - 25 June			29 June - 2 July			27 June - 28 June			25 June - 26 June			8 - 11 August		
Age Class	n	p	SE	n	p	SE	n	p	SE	n	p	SE	n	p	SE
1	5	0.05	0.02	0	---	---	7	0.07	0.03	0	---	---	0	---	---
2	26	0.27	0.05	8	0.08	0.03	7	0.07	0.03	3	0.02	0.01	56	0.27	0.03
3	19	0.20	0.04	21	0.22	0.04	17	0.17	0.04	44	0.22	0.03	27	0.13	0.02
4	40	0.42	0.05	43	0.44	0.05	48	0.48	0.05	33	0.16	0.03	22	0.11	0.02
5	6	0.06	0.03	21	0.22	0.04	11	0.11	0.03	79	0.39	0.03	69	0.33	0.03
6	0	---	---	4	0.04	0.02	7	0.07	0.03	25	0.12	0.02	18	0.09	0.02
7	0	---	---	0	---	---	3	0.03	0.02	16	0.08	0.02	15	0.07	0.02
8	0	---	---	0	---	---	0	---	---	4	0.02	0.01	1	0.01	0.01
9	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
10	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
11	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
12	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
Total	96	1.00		97	1.00		100	1.00		204	1.00		208	1.00	

-continued-

Appendix B2. (Page 4 of 4).

	1986[e] 11 - 15 August			1987[e] 3 - 10 August			1988[e] 8 - 11 August			1989[e] 8 - 10 August			1990[e] 8 - 10 August		
Age Class	n	p	SE	n	p	SE	n	p	SE	n	p[f]	SE[f]	n	p[f]	SE[f]
1	0	---	---	6	0.02	0.01	1	<0.01	<0.01	0	---	---	46	0.05	<0.01
2	80	0.14	0.02	55	0.15	0.02	144	0.18	0.01	364	0.47	0.02	79	0.08	<0.01
3	360	0.63	0.02	51	0.14	0.02	58	0.07	0.01	165	0.21	0.01	562	0.59	0.01
4	26	0.05	0.01	165	0.46	0.03	86	0.11	0.01	37	0.04	0.01	94	0.10	<0.01
5	37	0.07	0.01	9	0.03	0.01	317	0.40	0.02	104	0.09	0.01	36	0.04	<0.01
6	56	0.10	0.01	22	0.06	0.01	34	0.04	0.01	134	0.11	0.02	55	0.05	<0.01
7	8	0.01	0.01	32	0.09	0.02	67	0.09	0.01	44	0.03	<0.01	60	0.06	0.01
8	2	<0.01	<0.01	12	0.03	0.01	45	0.06	0.01	29	0.02	0.01	13	0.01	<0.01
9	2	<0.01	<0.01	5	0.01	0.01	20	0.03	0.01	7	0.01	<0.01	8	0.01	<0.01
10	0	---	---	1	<0.01	<0.01	8	0.01	<0.01	4	<0.01	<0.01	4	<0.01	<0.01
11	0	---	---	0	---	---	3	<0.01	<0.01	1	<0.01	0.00	0	---	---
12	0	---	---	0	---	---	1	<0.01	<0.01	0	---	---	0	---	---
Total	571	1.00		358	1.00		784	1.00		889	1.00		957	1.00	

[a] Data sources and gear type: 1955 - 1956, hook and line (H&L), Warner (1957); 1957, H&L, Warner (1958); 1958, seine, Warner (1959a); 1969, electrofishing boat (EB), Roguski and Tack (1970); 1973 - 1974, EB, Tack (1973,1974); 1975 - 1980, EB, Peckham (1976, 1977, 1978, 1979, 1980, 1981); 1982 - 1984, EB, Ridder (1983, 1985); 1985, EB, Holmes, et al. (1986); 1986 - 1987, EB, Clark and Ridder (1987, 1988); 1988, EB, Ridder (1989); 1989, EB, Clark and Ridder (1990); and 1990, EB, this report.

[b] n = sample size.

[c] p = proportion.

[d] SE = standard error of the proportion.

[e] For Arctic grayling greater than 149 mm FL only.

[f] Proportions and SE were adjusted to compensate for length bias found in the electrofishing sample.

Appendix B3. Summary of age composition estimates and standard errors for Arctic grayling sampled in the middle (53-98 km) and upper (98 - 152 km) sections of the Goodpaster River, summer, 1973 and 1979[a].

	1973[b] 15 June - 15 Aug middle			1973[b] 15 June - 15 Aug upper			1979 23 - 24 June upper		
Age Class	n[c]	p[d]	SE[e]	n	p	SE	n	p	SE
1	0	---	---	0	---	---	0	---	---
2	3	0.03	0.02	0	---	---	0	---	---
3	26	0.26	0.04	0	---	---	0	---	---
4	30	0.30	0.05	11	0.11	0.03	0	---	---
5	31	0.31	0.05	15	0.15	0.04	6	0.10	0.04
6	8	0.08	0.03	17	0.17	0.04	11	0.18	0.05
7	2	0.02	0.01	35	0.36	0.05	23	0.37	0.06
8	0	---	---	6	0.06	0.02	18	0.29	0.06
9	0	---	---	7	0.07	0.03	5	0.08	0.03
10	0	---	---	4	0.04	0.02	0	---	---
11	0	---	---	2	0.02	0.02	0	---	---
12	0	---	---	1	0.01	0.01	0	---	---
Total	100	1.00		98	1.00		63	1.00	

[a] Data sources and gear type: 1973 (middle) electrofishing boat, 1973 (upper) hook and line, Tack (1973, 1974); 1979, hook and line, Peckham (1979).
[b] For Arctic grayling greater than 149 mm FL only.
[c] n = sample size.
[d] p = proportion.
[e] SE = standard error of the proportion.

Appendix B4. Age composition estimates[a] for Arctic grayling weighted by three area population densities, Goodpaster River, 1973 and 1974.

Age Class	1973			1974		
	n[b]	p[c]	SE[d]	n	p	SE
2	ND[e]	0.03	ND	---	---	---
3	ND	0.45	ND	ND	0.07	ND
4	ND	0.28	ND	ND	0.52	ND
5	ND	0.13	ND	ND	0.20	ND
6	ND	0.05	ND	ND	0.06	ND
7	ND	0.04	ND	ND	0.06	ND
8	ND	0.01	ND	ND	0.01	ND
9	ND	0.01	ND	ND	<0.01	ND
10	ND	<0.01	ND	ND	<0.01	ND
11	ND	<0.01	ND	---	---	---
12	ND	<0.01	ND	---	---	---
Total	ND	1.00		277	1.00	

[a] Estimates developed from combining age proportions found in three river sections using the estimated population abundance in each section as a weighting factor. Data source is Tack (1974, 1975).
[b] n = sample size.
[c] p = proportion.
[d] SE = standard error of the proportion.
[e] ND = no data in citation.

Appendix B5. Summary of age composition estimates and standard errors for Arctic grayling sampled in the lower 16 km of the Goodpaster River, spring, 1982, 1985, 1986, and 1987[a].

	1982 15 - 16 May			1985 22 - 23 May			1986 16 - 17 May			1987 12 - 13 May		
Age Class	n[b]	p[c]	SE[d]	n	p	SE	n	p	SE	n	p	SE
1	2	0.01	0.01	0	---	---	0	---	---	0	---	---
2	4	0.02	0.01	0	---	---	9	0.03	0.01	4	0.01	0.01
3	26	0.12	0.02	11	0.03	0.01	67	0.20	0.02	2	0.01	0.01
4	30	0.14	0.02	32	0.08	0.01	31	0.09	0.02	49	0.16	0.02
5	29	0.13	0.02	136	0.35	0.02	34	0.10	0.02	11	0.04	0.01
6	45	0.20	0.03	53	0.14	0.02	92	0.28	0.02	28	0.09	0.02
7	29	0.13	0.02	85	0.22	0.02	48	0.14	0.02	72	0.24	0.03
8	33	0.15	0.02	25	0.06	0.01	32	0.10	0.02	53	0.18	0.02
9	16	0.07	0.02	31	0.08	0.01	10	0.03	0.01	45	0.15	0.02
10	7	0.03	0.01	10	0.03	0.01	5	0.02	0.01	16	0.05	0.01
11	1	0.01	<0.01	7	0.02	0.01	2	0.01	<0.01	15	0.05	0.01
12	0	---	---	0	---	---	3	0.01	0.01	3	0.01	0.01
13	0	---	---	0	---	---	2	0.01	<0.01	2	0.01	0.01
14	0	---	---	0	---	---	0	---	---	1	<0.01	<0.01
Total	222	1.00		390	1.00		335	1.00		301	1.00	

[a] All fish captured with an electrofishing boat. 1982 data from Ridder (1983) and Hop (1985); other data collected during an egg-take program (see Holmes, et al., 1986) and are from office files.

[b] n = sample size.

[c] p = proportion.

[d] SE = standard error of the proportion.

Appendix B6. Summary of age composition estimates and standard errors for adult Arctic grayling sampled in the lower 16 km of the Goodpaster River, spring, 1982, 1985, 1986, and 1987[a].

	1982 15 - 16 May			1985 22 - 23 May			1986 16 - 17 May			1987 12 - 13 May			Total		
Age Class	n[b]	p[c]	SE[d]	n	p	SE	n	p	SE	n	p	SE	n	p	SE
5	14	0.10	0.03	3	0.02	0.01	1	0.01	0.01	2	0.01	0.01	20	0.03	0.01
6	41	0.29	0.04	25	0.16	0.03	43	0.31	0.04	22	0.10	0.02	131	0.20	0.02
7	29	0.21	0.03	62	0.39	0.04	43	0.31	0.04	68	0.30	0.03	202	0.30	0.02
8	33	0.23	0.04	23	0.14	0.03	32	0.23	0.04	52	0.23	0.03	140	0.21	0.02
9	16	0.11	0.03	31	0.19	0.03	10	0.07	0.02	45	0.20	0.03	102	0.15	0.01
10	7	0.05	0.02	10	0.06	0.02	5	0.04	0.02	16	0.07	0.02	38	0.06	0.01
11	1	0.01	0.01	7	0.04	0.02	2	0.01	0.01	15	0.07	0.02	25	0.04	0.01
12	0	---	---	0	---	---	3	0.02	0.01	3	0.01	0.01	6	0.01	<0.01
13	0	---	---	0	---	---	2	0.01	0.01	2	0.01	0.01	4	0.01	<0.01
14	0	---	---	0	---	---	0	---	---	1	<0.01	<0.01	1	<0.01	<0.01
Total	141	1.00		161	1.00		141	1.00		226	1.00		669	1.00	

[a] All fish captured with an electrofishing boat. Determination of adult fish was made by sexual dimorphism and/or reproductive products. 1982 data from Ridder (1983) and Hop (1985); other data collected during an egg-take program (see Holmes et al., 1986) and are from office files.

[b] n = sample size.

[c] p = proportion.

[d] SE = standard error of the proportion.

Appendix B7. Summary of mean length at age data for Arctic grayling sampled in the Goodpaster River, summer, 1969 - 1990[a].

	1969 summer			1973 15 June-15 August			1975 23-24 June			1976 21-22 June			1977 21-22 June			1978 21-22 June		
Age Class	n[b]	FL[c]	SD[d]	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
1	0	---	---	0	---	---	3	82	ND	1	108	ND	8	98	ND	2	101	ND
2	9	126	ND[e]	3	146	ND	3	149	ND	13	149	ND	1	151	ND	23	140	ND
3	13	171	ND	91	181	ND	52	182	ND	13	187	ND	76	175	ND	13	188	ND
4	12	215	ND	68	224	ND	7	207	ND	44	209	ND	6	229	ND	58	208	ND
5	11	265	ND	48	276	ND	29	233	ND	25	240	ND	13	245	ND	8	268	ND
6	9	297	ND	28	317	ND	5	269	ND	22	264	ND	12	273	ND	0	---	---
7	4	330	ND	37	343	ND	1	346	ND	1	285	ND	0	---	---	0	---	---
8	7	351	ND	6	368	ND	0	---	---	1	364	ND	0	---	---	0	---	---
9	4	362	ND	7	396	ND	0	---	---	0	---	---	0	---	---	0	---	---
10	1	378	ND	4	404	ND	0	---	---	0	---	---	0	---	---	0	---	---
11	0	---	---	3	417	ND	0	---	---	0	---	---	0	---	---	0	---	---
12	0	---	---	1	432	ND	0	---	---	0	---	---	0	---	---	0	---	---
Total	70			295			100			120			116			104		

-continued-

Appendix B7. (Page 2 of 3).

	1979 25-28 June			1980 24-25 June			1982 29-30 June			1984 27-28 June			1985[f] 25-26 June			1985[f] 6-8 August		
Age Class	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
1	0	---	---	5	105	ND	0	---	---	7	92	ND	0	---	---	0	---	---
2	0	---	---	26	156	ND	8	133	ND	7	161	ND	3	160	6	56	164	15
3	0	---	---	19	202	ND	21	191	ND	17	204	ND	44	190	12	27	208	10
4	0	---	---	40	220	ND	43	218	ND	48	219	ND	33	224	14	22	236	14
5	6	281	ND	6	260	ND	21	249	ND	11	259	ND	79	245	19	69	253	17
6	11	320	ND	0	---	---	4	270	ND	7	258	ND	25	269	20	18	284	13
7	23	359	ND	0	---	---	0	---	---	3	289	ND	16	284	21	15	292	20
8	18	379	ND	0	---	---	0	---	---	0	---	---	4	323	25	1	295	---
9	5	395	ND	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
10	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
11	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
12	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
Total	63			96			97			100			204	236	37	208	227	47

-Continued-

Appendix B7. (Page 3 of 3).

	1986[f] 11-15 August			1987[f] 3-10 August			1988[f] 8-11 August			1989[f] 8-10 August			1990[f] 8-10 August		
Age Class	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
1	0	---	---	6	166	17	1	155	---	0	---	---	46	156	5
2	80	164	9	55	183	15	144	187	13	364	171	11	79	182	11
3	360	193	19	51	206	14	58	221	14	165	220	14	562	214	15
4	26	235	15	165	233	13	86	243	16	37	253	17	94	252	20
5	37	261	12	9	264	15	317	268	17	104	277	19	36	278	23
6	56	281	22	22	276	14	34	296	17	134	296	18	55	297	26
7	8	305	23	32	288	17	67	307	20	44	315	19	60	311	24
8	2	301	8	12	296	17	45	321	22	29	332	17	13	321	28
9	2	387	27	5	341	34	20	336	33	7	354	19	8	345	18
10	0	---	---	1	311	---	8	352	15	4	384	21	4	365	57
11	0	---	---	0	---	---	3	376	33	1	378	---	0	---	---
12	0	---	---	0	---	---	1	391	---	0	---	---	0	---	---
Total	571	211	72	358	233	38	784	254	46	889	230	59	957	228	45

[a] Data sources and gear type: 1969, electrofishing boat (EB), Roguski and Tack (1970); 1973 - 1974, EB, Tack (1973,1974); 1975 - 1980, EB, Peckham (1976, 1977, 1978, 1979, 1980, 1981); 1982 - 1984, EB, Ridder (1983, 1985); 1985, EB, Holmes, et al. (1986); 1986 - 1987, EB, Clark and Ridder (1987, 1988); 1988, Ridder (1989); 1989, Clark and Ridder (1990); and, 1990, this report.

[b] n = sample size.

[c] FL = mean fork length (mm) at age.

[d] SD = sample standard deviation of FL.

[e] ND = no data in citation.

[f] For Arctic grayling greater than 149 mm FL only.

Appendix B8. Summary of mean length at age data for Arctic grayling sampled in the lower 16 km of the Goodpaster River, spring, 1982, 1985 through 1986[a].

	1982 15 - 16 May			1985 22 - 23 May			1986 16 - 17 May			1987 12 - 13 May		
Age Class	n[b]	FL[c]	SD[d]	n	FL	SD	n	FL	SD	n	FL	SD
1	2	96	11	0	---	---	0	---	---	0	---	---
2	4	137	21	0	---	---	9	133	23	4	183	12
3	26	195	9	11	193	9	67	175	20	2	160	10
4	30	217	10	32	224	15	31	221	15	49	224	21
5	29	262	20	136	250	21	34	252	16	11	280	21
6	45	293	31	53	279	17	92	276	21	28	303	21
7	29	311	36	85	301	28	48	305	18	72	328	22
8	33	337	29	25	323	21	32	317	22	53	338	27
9	16	349	24	31	355	23	10	378	25	45	363	21
10	7	368	24	10	365	28	5	385	25	16	379	23
11	1	383	---	7	381	16	2	405	24	15	393	20
12	0	---	---	0	---	---	3	414	26	3	418	10
13	0	---	---	0	---	---	2	416	14	2	371	4
14	0	---	---	0	---	---	0	---	--	1	472	---
Total	222	278	63	390	280	48	335	259	64	301	320	59

[a] All fish captured with an electrofishing boat. 1982 data from Ridder (1983) and Hop (1985); other data collected during an egg-take program (see Holmes, et al. 1986) and are from office files.

[b] n = sample size.

[c] FL = mean fork length (mm) at age.

[d] SD = sample standard deviation of FL.

Appendix B9. Summary of mean length at age data for adult male Arctic grayling sampled in the lower 16 km of the Goodpaster River, spring, 1982, 1985 through 1987[a].

	1982 15 - 16 May			1985 22 - 23 May			1986 16 - 17 May			1987 16 - 17 May			Total		
Age Class	n[b]	FL[c]	SD[d]	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
5	8	276	11	2	304	49	0	---	---	1	339	---	11	286	30
6	21	298	35	7	291	17	21	292	19	15	308	24	64	297	27
7	16	311	42	19	321	30	19	313	17	49	332	22	103	323	28
8	26	337	30	5	329	13	14	318	18	36	344	28	81	336	28
9	11	351	24	11	360	21	4	361	22	37	364	21	63	361	22
10	7	368	24	4	379	35	4	385	23	12	383	25	27	379	27
11	1	383	---	2	394	7	2	405	24	12	390	20	17	391	20
12	0	---	---	0	---	---	3	414	26	3	418	10	6	416	20
13	0	---	---	0	---	---	2	416	14	2	371	4	4	393	25
14	0	---	---	0	---	---	0	---	---	1	472	---	1	472	---
Total	90	322	41	50	333	39	69	325	42	168	350	36	377	337	41

[a] All fish captured with an electrofishing boat. Determination of adult fish was made by sexual dimorphism and/or reproductive products. 1982 data from Ridder (1983) and Hop (1985); other data collected during an egg-take program (see Holmes, et al. 1986) and are from office files.

[b] n = sample size.

[c] FL = mean fork length (mm) at age.

[d] SD = sample standard deviation of FL.

Appendix B10. Summary of mean length at age data for adult female Arctic grayling sampled in the lower 16 km of the Goodpaster River, spring, 1982, 1985 through 1987[a].

	1982 15 - 16 May			1985 22 - 23 May			1986 16 - 17 May			1987 12 - 13 May			Total		
Age Class	n[b]	FL[c]	SD[d]	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
5	6	280	11	1	248	---	1	253	---	1	296	---	9	275	17
6	20	296	24	18	283	18	22	287	22	7	298	9	67	290	21
7	13	310	25	43	301	26	24	302	16	19	320	19	99	306	24
8	7	334	23	18	322	23	18	317	24	16	326	19	59	323	23
9	5	345	25	20	352	24	6	344	24	8	360	22	39	351	24
10	0	---	---	6	356	17	1	351	---	4	367	13	11	360	16
11	0	---	---	5	376	16	0	---	---	3	405	12	8	387	20
Total	51	307	30	111	316	37	72	304	27	58	333	33	292	313	34

[a] All fish captured with an electrofishing boat. Determination of adult fish was made by sexual dimorphism and/or reproductive products. 1982 data from Ridder (1983) and Hop (1985); other data collected during an egg-take program (see Holmes, et al. 1986) and are from office files.

[b] n = sample size.

[c] FL = mean fork length (mm) at age.

[d] SD = sample standard deviation of FL.

Appendix B11. Summary of Relative Stock Density (RSD) estimates for Arctic grayling (≥ 150 mm FL) in the lower Goodpaster River, 1955 - 1990[a].

		RSD Category[b]				
		Stock	Quality	Preferred	Memorable	Trophy
1955	Number sampled	118	45	10	0	0
Jul-	RSD	0.68	0.26	0.06	---	---
Sept	Standard Error	0.04	0.03	0.02	---	---
1956	Number sampled	204	31	4	0	0
Jun-	RSD	0.85	0.13	0.02	---	---
Aug	Standard Error	0.02	0.02	0.01	---	---
1970	Number sampled	802	42	0	0	0
Aug	RSD	0.95	0.05	---	---	---
	Standard Error	0.01	0.01	---	---	---
1972	Number sampled	163	9	0	0	0
Jun	RSD	0.95	0.05	---	---	---
	Standard Error	0.02	0.02	---	---	---
1972	Number sampled	120	2	0	0	0
Aug	RSD	0.98	0.02	---	---	---
	Standard Error	0.01	0.01	---	---	---
1975	Number sampled	636	12	1	0	0
Jun	RSD	0.98	0.02	<0.01	---	---
	Standard Error	<0.01	0.01	<0.01	---	---
1976	Number sampled	337	18	2	0	0
Jun	RSD	0.94	0.05	0.01	---	---
	Standard Error	0.01	0.01	<0.01	---	---
1977	Number sampled	633	15	1	0	0
Jun	RSD	0.98	0.02	<0.01	---	---
	Standard Error	0.01	0.01	<0.01	---	---
1978	Number sampled	603	17	0	0	0
Jun	RSD	0.97	0.03	---	---	---
	Standard Error	0.01	0.01	---	---	---
1980	Number sampled	588	12	0	0	0
Jun	RSD	0.98	0.02	---	---	---
	Standard Error	0.01	0.01	---	---	---

-continued-

Appendix B11. (Page 2 of 3).

		RSD Category[b]				
		Stock	Quality	Preferred	Memorable	Trophy
1982 May	Number sampled	112	102	37	0	0
	RSD	0.45	0.41	0.15	---	---
	Standard Error	0.03	0.03	0.02	---	---
1982 Jun	Number sampled	314	11	0	0	0
	RSD	0.97	0.03	---	---	---
	Standard Error	0.01	0.01	---	---	---
1984 Jun	Number sampled	443	39	0	0	0
	RSD	0.92	0.08	---	---	---
	Standard Error	0.01	0.01	---	---	---
1985 May	Number sampled	217	210	80	0	0
	RSD	0.43	0.41	0.16	---	---
	Standard Error	0.02	0.02	0.02	---	---
1985 Jun	Number sampled	169	35	1	0	0
	RSD	0.82	0.17	0.01	---	---
	Standard Error	0.03	0.03	0.01	---	---
1985 Aug	Number sampled	322	60	0	0	0
	RSD	0.84	0.16	---	---	---
	Standard Error	0.02	0.02	---	---	---
1986 May	Number sampled	167	151	28	0	0
	RSD	0.48	0.44	0.08	---	---
	Standard Error	0.03	0.03	0.02	---	---
1986 Aug	Number sampled	560	80	6	0	0
	RSD	0.87	0.12	0.01	---	---
	Standard Error	0.01	0.01	<0.01	---	---
1987 May	Number sampled	58	128	130	1	0
	RSD	0.18	0.40	0.41	<0.01	---
	Standard Error	0.02	0.03	0.03	<0.01	---
1987 Aug	Number sampled	290	66	2	0	0
	RSD	0.81	0.18	0.01	---	---
	Standard Error	0.02	0.02	<0.01	---	---

-continued-

Appendix B11. (Page 3 of 3).

		RSD Category[b]				
		Stock	Quality	Preferred	Memorable	Trophy
1988	Number sampled	1,213	725	73	0	0
Aug	RSD	0.60	0.36	0.04	---	---
	Standard Error	0.01	0.01	<0.01	---	---
1989	Number sampled	1,239	515	62	0	0
Aug	Sampled RSD	0.68	0.28	0.03	---	---
	Adjusted RSD[c]	0.78	0.20	0.02		
	Standard Error[d]	0.02	0.02	<0.01	---	---
1990	Number sampled	1,234	244	46	0	0
Aug	Sampled RSD	0.81	0.16	0.03	---	---
	Adjusted RSD[c]	0.84	0.14	0.02		
	Standard Error[d]	0.02	0.02	<0.01	---	---

[a] Data Sources: 1955-1956, Warner (1957); 1970, 1972, Tack (1971, 1973); 1975- 1982 (June), Peckham (1976, 1977, 1978, 1979, 1983); 1984, Ridder (1985); 1982 (May), 1985, 1986, 1987 (May), Office files; 1987 (Aug), Clark and Ridder (1988); 1988, Ridder (1989); 1989, Clark and Ridder (1990); and, 1990, this report.

[b] Minimum lengths (FL) for RSD categories are (Gabelhouse 1984):
Stock - 150 mm
Quality - 270 mm
Preferred - 340 mm
Memorable - 450 mm
Trophy - 560 mm

[c] RSD adjusted due to bias in length selectivity of the electrofishing boat.

[d] Standard error of the adjusted RSD.

Appendix B12. Summary of Relative Stock Density (RSD) estimates for adult Arctic grayling (≥ 150 mm FL) in the lower 16 km of the Goodpaster River, spring, 1982 and 1985 through 1987.

		RSD Category[a]				
		Stock	Quality	Preferred	Memorable	Trophy
1982	Number sampled	17	99	37	0	0
	RSD	0.11	0.65	0.24	---	---
	Standard Error	0.03	0.04	0.04	---	---
1985	Number sampled	20	141	80	0	0
	RSD	0.08	0.59	0.33	---	---
	Standard Error	0.02	0.02	0.03	---	---
1986	Number sampled	8	109	24	0	0
	RSD	0.06	0.77	0.17	---	---
	Standard Error	0.02	0.04	0.03	---	---
1987	Number sampled	1	108	130	1	0
	RSD	<0.01	0.45	0.54	<0.01	---
	Standard Error	<0.01	0.03	0.03	<0.01	---
Total	Number sampled	46	457	271	1	0
	RSD	0.06	0.59	0.35	<0.01	---
	Standard Error	0.01	0.02	0.02	<0.01	---

[a] Minimum lengths (FL) for RSD categories are (Gabelhouse 1984):
Stock - 150 mm
Quality - 270 mm
Preferred - 340 mm
Memorable - 450 mm
Trophy - 560 mm

Appendix B13. Summary of Relative Stock Density (RSD) indices for adult Arctic grayling (≥ 150 mm FL) by sex in the lower 16 km of the Goodpaster River, spring, 1982 and 1985 through 1987.

		RSD Category[a]				
		Stock	Quality	Preferred	Memorable	Trophy
1982	Males:					
	Number sampled	10	51	30	0	0
	RSD	0.11	0.56	0.33	---	---
	Standard Error	0.03	0.05	0.05	---	---
1982	Females:					
	Number sampled	7	48	7	0	0
	RSD	0.11	0.77	0.11	---	---
	Standard Error	0.04	0.05	0.04	---	---
1985	Males:					
	Number sampled	4	39	44	0	0
	RSD	0.05	0.45	0.51	---	---
	Standard Error	0.02	0.05	0.05	---	---
1985	Females:					
	Number sampled	16	102	36	0	0
	RSD	0.10	0.66	0.23	---	---
	Standard Error	0.03	0.04	0.03	---	---
1986	Males:					
	Number sampled	2	56	20	0	0
	RSD	0.03	0.72	0.26	---	---
	Standard Error	0.02	0.05	0.05	---	---
1986	Females:					
	Number sampled	7	66	8	0	0
	RSD	0.09	0.82	0.10	---	---
	Standard Error	0.03	0.04	0.03	---	---
1987	Males:					
	Number sampled	1	68	110	1	0
	RSD	0.01	0.38	0.61	0.01	---
	Standard Error	0.01	0.04	0.04	0.01	---
1987	Females:					
	Number sampled	0	40	20	0	0
	RSD	---	0.67	0.33	---	---
	Standard Error	---	0.06	0.06	---	---

-continued-

Appendix B13. (Page 2 of 2).

	RSD Category				
	Stock	Quality	Preferred	Memorable	Trophy
Total <u>Males:</u>					
Number sampled	17	214	204	1	0
RSD	0.04	0.49	0.47	<0.01	---
Standard Error	0.01	0.02	0.02	<0.01	---
Total <u>Females:</u>					
Number sampled	30	256	71	0	0
RSD	0.08	0.72	0.20	---	---
Standard Error	0.02	0.02	0.02	---	---

[a] Minimum lengths (FL) for RSD categories are (Gabelhouse 1984):
Stock - 150 mm
Quality - 270 mm
Preferred - 340 mm
Memorable - 450 mm
Trophy - 560 mm

Appendix B14. Arctic grayling abundance, harvest, and angler exploitation estimates for the Goodpaster River, 1972 through 1990.

Year	Month	Abundance[a] 0-53km	Abundance[a] 0-152km	Harvest	Angler exploitation[b] 0-53	Angler exploitation[b] 0-152
1972	JUNE	10,017	20,034	ND[c]	---	---
1973	JUNE	25,440	44,955	2,236	0.09	0.05
1974	JUNE	10,649	27,441	ND	---	---
1975	JUNE	25,166	50,332	ND	---	---
1976	JUNE	18,654	37,307	ND	---	---
1977	JUNE	19,999	39,998	ND	---	---
1978	JUNE	25,054	50,108	ND	---	---
1979	JUNE	ND	ND	ND	---	---
1980	JUNE	25,574	51,149	ND	---	---
1981	JUNE	ND	ND	ND	---	---
1982	JUNE	8,616	17,232	ND	---	---
1983	JUNE	ND	ND	3,021	---	---
1984	JUNE	18,656	37,312	1,194	0.06	0.03
1985	AUGUST	19,292	38,584	2,757	0.13[d]	0.07[d]
1986	AUGUST	16,165	32,330	1,508	0.09[d]	0.05[d]
1987	AUGUST	7,102	14,204	1,702	0.19[d]	0.11[d]
1988	AUGUST	8,374	16,748	1,273	0.13[d]	0.07[d]
1989	AUGUST	8,033	16,066	1,964	0.20[d]	0.11[d]
1990	AUGUST	7,113	14,226	(1,917)[e]	0.21[d]	0.12[d]
Averages:		15,895	31,736	1,917	0.12	0.07

[a] Abundance in the lower 53 km for 1972 and 1975 through 1988 was extrapolated from fish per km estimates (Appendix Table B1). Abundance for 0 - 152 km for the same years is twice the estimate for the lower 53 km based on the average ratio between the sections estimated in 1973 and 1974 (Appendix Table B1).

[b] Exploitation rate is harvest divided by abundance.

[c] ND = no data.

[d] Harvests were added to abundance estimates to give an approximation of abundance at start of season prior to calculating exploitation rates.

[e] Average harvest was used in order to obtain exploitation estimates.

APPENDIX C
Methods For Alleviating Bias

Appendix C1. Methodologies for alleviating bias due to gear selectivity by means of statistical inference.

Result of first K-S test[a]	Result of second K-S test[b]
Case I[c]	
Fail to reject H_0	Fail to reject H_0
Inferred cause: There is no size-selectivity during either sampling event.	
Case II[d]	
Fail to reject H_0	Reject H_0
Inferred cause: There is no size-selctivity during the second sampling event, but there is during the first sampling event	
Case III[e]	
Reject H_0	Fail to reject H_0
Inferred cause: There is size-selectivity during both sampling events.	
Case IV[f]	
Reject H_0	Reject H_0
Inferred cause: There is size-selectivity during the second sampling event; the status of size-selectivity during the first event is unknown.	

[a] The first K-S (Kolmogorov-Smirnov) test is on the lengths of fish marked during the first event versus the lengths of fish recaptured during the second event. H_0 for this test is: The distribution of lengths of fish sampled during the first event is the same as the distribution of lengths of fish recaptured during the second event.

[b] The second K-S test is on the lengths of fish marked during the first event versus the lengths of fish captured during the second event. H_0 for this test is: The distribution of lengths of fish sampled during the first event is the same as the distribution of lengths of fish sampled during the second event.

[c] Case I: Calculate one unstratified abundance estimate, and pool lengths and ages from both sampling event for size and age composition estimates.

[d] Case II: Calculate one unstratified abundance estimate, and only use lengths and ages from the second sampling event to estimate size and age composition.

[e] Case III: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata. Pool lengths and ages from both sampling events and adjust composition estimates for differential capture probabilities.

[f] Case IV: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata. Also calculate a single abundance estimate without stratification.
If stratified and unstratified estimates are dissimilar, discard unstratified estimate and use lengths and ages from second event and adjust these estimates for differential capture probabilities.
If stratified and unstratified estimates are similar, discard estimate with largest variance. Use lengths and ages from first sampling event to directly estimate size and age compositions.

APPENDIX D
Data File Listing

Appendix D1. Data files[a] used to estimate parameters of Arctic grayling populations in the Salcha, Chatanika, and Goodpaster rivers, 1990

Data file	Description
U005ALA0.DTA	Population and marking data for Arctic grayling captured during the first event at the Salcha River, 19 through 22 June 1990.
U005ALB0.DTA	Population and marking data for Arctic grayling captured during the second event at the Salcha River, 26 and 27 June 1990.
U004CLA0.DTA	Population and marking data for Arctic grayling captured during the first event at the Chatanika River, 27 through 30 August 1990.
U004DLA0.DTA & U004ELA0.DTA	Population and marking data for Arctic grayling captured during the second event at the Chatanika River, 6 and 7 September 1990.
U0080LA0.DTA	Population and marking data for Arctic grayling captured during the first event at the Goodpaster River, 8 through 10 August 1990.
U0080LB0.DTA	Population and marking data for Arctic grayling captured during the second event at the Goodpaster River, 14 through 16 August 1990.

[a] Data files have been archived at and are available from the Alaska Deprtament of Fish and Game, Sport Fish Division, Research and Technical Services, 333 Raspberry Road, Anchoarge, Alaska 99518-1599.